CASS Technical Report

Manna Fish Farms: Aquaculture Siting Analysis Results

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INTRODUCTION

Planning and siting for developing marine aquaculture operations requires synthesis and spatial analyses of key environmental and ocean-space use conflicts to determine the highest likelihood of long-term success. Implementing this planning strategy ensures compatibility and works towards environmental and economically sustainable operations. Aquaculture siting analyses involve the use of geospatial analytical tools (e.g., GIS – Geographic Information Systems) to integrate pertinent spatial data and generate map-based products that can be used to inform policy and permitting decisions regarding aquaculture operations.

Manna Fish Farms (hereafter 'Manna') is led by Donna Lanzetta, CEO of Long Island, New York. Manna has assembled a team of local and worldwide marine scientists, biologists, engineers, aquatic veterinarians, along with aquaculture, operational and educational experts to implement this farming initiative. Please see http://mannafishfarms.com for more information.

This technical report covers NOAA's Coastal Aquaculture Siting and Sustainability (CASS) Program objective alternative siting analysis for the proposed Manna finfish farm project. This siting analysis utilized the best available, high-resolution spatial data to represent key potential environmental and ocean use conflicts that constrain, or conditionally constrain, the siting of aquaculture in the federal waters of the Northeastern United States. The siting analysis was guided by quantitative input provided by Manna regarding specific project requirements and was iteratively developed with input provided by the United States Army Corps of Engineers (USACE), NOAA, Northeast Regional Aquaculture Coordinator (Kevin Madley), and the Manna team. The purpose of this analysis is to inform the permitting process for Manna fish farms or other aquaculture projects located within the general area of this analysis.

The **Coastal Aquaculture Siting and Sustainability (CASS)** program supports NOAA and NCCOS missions by delivering science-based decision support tools to local, state, and federal coastal managers. The CASS program works to support coastal planning for marine aquaculture including operating, monitoring, and assessing aquaculture impacts in coastal environments.

Learn about CASS and how we are growing sustainable marine aquaculture practices at: http://coastalscience.noaa.gov/research/scem/marine_aquaculture or contact Dr. James Morris at James.Morris@noaa.gov.

METHODS

Initially, after considering multiple analytical approaches, it was decided a multi-criteria decision analysis was needed to determine the most suitable farm site. The USACE initially defined two areas of interest that the siting analysis should focus on for the formation of alternative sites (Figure 1).

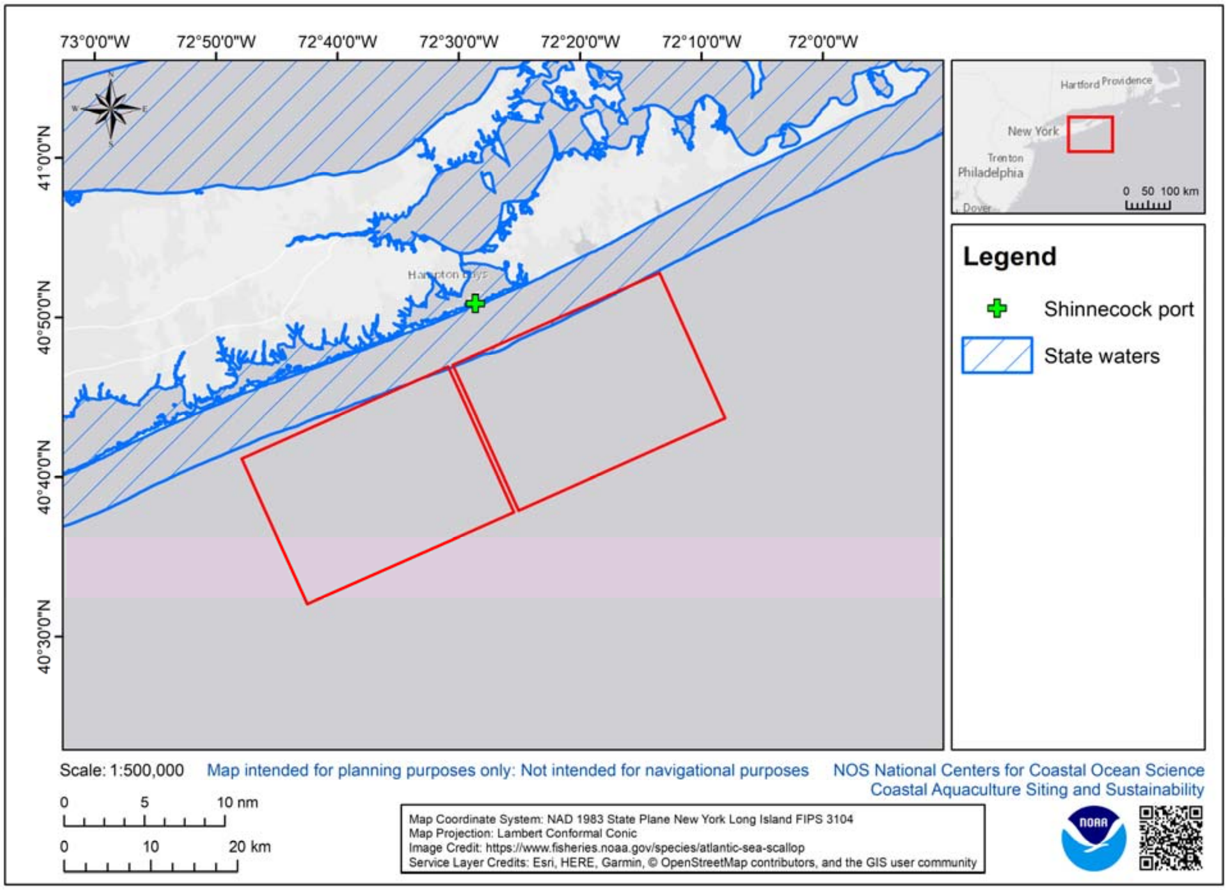


Figure 1: Initial areas (red boxes) defined by USACE for the farm siting analysis.

Data Inventory

A comprehensive spatial data inventory was developed for the waters south of Suffolk County, New York to inform the Manna siting analysis. Specifically, this includes data layers from the following categories: farm requirements, military, navigation, industry and recreation, commercial fishing activity, natural resources, and oceanographic / biophysical. A broad suite of state and federal agencies (e.g., NOAA National Marine Fisheries Service, U.S. Department of Defense, Bureau of Ocean Energy Management, New York State Department of Conservation, NOAA OCM) and academic institutions (e.g., Stoney Brook University, New Hampshire University) contributed data resources. Many data sources were viewed and downloaded from the Northeast Ocean Data Portal (https://www.northeastoceandata.org/). Data were checked for completeness and quality, and the most authoritative sources were used where possible. All data were projected in NAD 1983 State Plane New York Long Island FIPS 3104, WKID: 32118, Authority: EPSG. See Appendix A for complete data inventory generated for the siting analysis (Table A-1).

Project Requirements

Manna coordinators provided quantitative requirements for the Manna project. These included the following items of information: 1) spatial boundaries for region of interest, 2) preference for state or federal waters, 3) preferred project location coordinates, 4) approximate proposed project size, 5) preferred port, 6) maximum distance from preferred port, 7) species to be cultivated, 8) acceptable depth range, 9) acceptable seawater temperature range, 10) acceptable current velocity range, 11) maximum allowable wave energy, and 12) preferred substrate. This information was obtained via email communication and documented herein.

Spatial Analysis Development

The first step in the siting process was to acquire and quality control available data resources needed for aquaculture siting in the Northeastern United States' federal waters. The analysis starts with identifying needs of the farm, regional farm location, and then accounts for practical operational, biophysical, and oceanographic constraints and considerations. Military operations in the Area of Interest (AOI) were first mapped and discussed. The Narragansett Operating Complex (including W-105, W-106, which are both Special Use Air Space) is adjacent to the coasts of Rhode Island and Long Island, New York, and is operated by the Fleet Area Control and Surveillance Facility, Virginia Capes (FACSFAC VACAPES) Naval Air Station Oceana. Military training activities may be conducted within these areas, and compatibility must be considered for aquaculture operations. For instance, submarine transit lanes or warning area W – 105, which is used for surface to air gunnery exercises using conventional ordnance and antisubmarine Warfare (ASW) exercises, should both be avoided. These areas have incompatibilities with aquaculture and extend from the surface to seafloor as exercises are performed throughout the water column (NSSC 2018). Therefore the operating area itself is conditionally constrained, as the military will need to assess the risk and compatibility of aquaculture operations. Warning areas inside the operating area (i.e., W-105, W-106, submarine transit lanes) were considered as being higher risk than the operating area outside the warning areas for siting aquaculture. For more information please refer to https://www.globalsecurity.org/military/facility/moa-narra.htm.

Next, data were gathered for determining relative interference with navigation and navigational routes. Automated Identification System (AIS) data (OCM 2018) were analyzed to determine the relative vessel count (i.e., vessel traffic) of each vessel type (i.e., tanker, cargo, passenger, tug and tow, pleasure and sailing, and other vessels – military and police) within the area of interest. Additionally relevant industry data (e.g., commercial fishing activity) and any sensitive habitat or protected species data were gathered. Sensitive habitats include designated areas, such as Habitat Areas of Particular Concern. Protected species included cetaceans (e.g., Fin whales), seabirds, and various species of sea turtles, as well as section 7 management areas. It is difficult to include large highly migratory species in a weighted spatial analysis, unless a wealth of empirical data are available. Density estimates for cetaceans for the East coast are available (MDAT – Marine-life Data Analysis Team), however at the siting level, data at a spatial resolution of 1 arc degree is not informative. Supplemental data was received from the NYSERDA seasonal digital aerial surveys conducted by the New York Department of Conservation. The Northeast does have ongoing data and data collection efforts for migratory species, some of which are presented herein. Consultation with the protected resources biologist will be imperative in permitting and final siting.

All of the aforementioned data are aquaculture-relevant and should be considered in a siting analysis (Table 1). Here, all of these parameters were considered within a weighted spatial approach to determine the most suitable sites for offshore aquaculture given the farm parameters.

Spatial Analysis

A relative suitability analysis, a form of a multi-criteria analysis, was carried out for the Manna project. A relative suitability analysis examines multiple spatial data layers to identify locations in a predefined area with the highest suitability relative to other locations, in this case for aquaculture. A uniform gird was created for the Area of Interest (AOI) guided by the USACE (Figure 1). The grid cell size began as the farm footprint (1.5 mi^2), and was then quartered to 0.375 mi^2 (four grid cells equal one farm footprint) to reduce unnecessary exclusions (Figure 2). Continuous data layers, such as bathymetry or commercial fishing activity, were treated by using the mean of all values within a grid cell to determine the score based on the defined scoring schema. For discrete data layers, such as distance from shore or whale watching areas, if any part of the grid cell intersected the layer, the entire cell was classified according to the layers scoring schema. The AOI was further refined using firm thresholds for depth and distance from port (Figure 3). Aquaculture-relevant spatial data layers were examined in relation to the AOI. Layers with no overlap or lacking high spatial resolution within the AOI were not considered within this suitability analysis, but were noted within this report. Overall twenty-one spatial data layers were included for this suitability analysis. All included layers were re-scaled to a weighted scoring schema from 0 to 1, 0 being unsuitable and 1 being suitable for aquaculture. Intervals for scoring could be broken down in the tenths (i.e., 0.1 - 0.9) depending on the variable. For example, a grid cell with vessel traffic would receive a lower score than a cell with no vessel traffic. In addition, if any grid cell received a score of 0 for any layer, that grid cell received a final score of 0 (e.g. A submarine cable present in a grid cell would 0 out the cell for the entire analysis). Relative suitability scores for each group and overall were calculated by summing the scores of each data layer for each cell and dividing by the total number of layers. Cells with scores closer to 1 are considered to be more suitable than cells closer to 0, with cells having a value of 0 being considered unsuitable in this aquaculture siting analysis.

As mentioned above, some layers (biological) were considered, but were not in the final aquaculture suitability analysis. For instance, the data for protected species that are highly mobile create a complex set of spatial and temporal considerations. Due to many of these organisms (e.g., whales, sea turtles) falling under the Endangered Species Act, it is important to consult with regional experts before final site selection.

Table 1. Categorized data layers were examined and if within the Area of Interest (AOI) included in the relative suitability analysis.

Category	Data Layer
Farm Parameter	Distance from Port
	Depth
	Substrate
	Temperature
	Velocity
	Wave height
Military	Danger and Restricted Zones
	Naval/Air Force Operational Areas
	Unexploded ordnances
	Special Use Air space
Navigation	Shipping fairways
	Ocean Disposal sites
	Anchorage areas
	Pilot Boarding Areas
	Regulated Navigational Areas
	Submarine Cables/ Cable Areas
	Shipwrecks / Obstructions / Artificial reefs
	AIS Vessel traffic (by vessel type)
Industry	Wind Energy Leases /Planning Areas
	Recreation Diving / Whale Watching
	Commercial Fishing Activity
Biological	Marine mammals
	Sea Turtles
	Seabirds
	Submerged Aquatic Vegetation
	Protected/Regulated Areas

RESULTS

FARM REQUIREMENTS

New offshore aquaculture operations are unique in location, gear requirements, cultivated species, carrying capacity, inshore infrastructure, telecommunication needs, and potential ecosystem and industry concerns. NOAA therefore gathered the following information for the Manna project presented in Table 2.

Table 2. The following farm requirements were received from the Manna team (All prompts were optional).

Prompt with Response	
Spatial Boundaries of Region of Interest:	≤ 8 nautical miles from Shinnecock Bay
Preference for State or Federal Waters:	Federal Waters
Preferred Project Location Coordinates:	(Lat., Lon., in DD) (-72.36, -72.36), (40.7496, 72.3425), (40.7262, -72.3434), (40.7266, -72.3609)
Approximate Proposed Project Size:	3.88 km² (1.5 mi²)
Preferred Port:	Shinnecock Bay
Maximum Distance from Preferred Port:	≤ 8 nautical miles from port (radius)
Species to be Cultivated:	Steelhead Trout (*Oncorhynchus mykiss*) or Atlantic Striped Bass (*Morone saxatilis*)
Acceptable Depth Range:	37 – 50 m (40 m is ideal)
Acceptable Seawater Temperature Range:	10 – 25 °C, (20 °C, 16 °C respectively)
Acceptable Current Velocity Range:	≤ 0.5 m/s is optimal, ≤ 0.8 m/s is suitable
Maximum Allowable Wave Energy:	3 m Hs (20-year average)
Ideal Substrate:	Mud, sand, or mixed sediment

Initially, a large Area of Interest (AOI) was identified (~1056 km²) south of Shinnecock Port, Long Island, NY (Figures 1 and 2). Farm logistics required the location to be less than or equal to 8 nm from port and engineering requirements for the net pen required depths greater than 37 m (Figure 3, Table 3). Once these parameters were considered, a smaller AOI of ~130 km² was identified (Figure 3). Temperature and significant wave height (Hs) data were collected from the Montauk Point buoy (Station 44017, 40.693, -72.049) (NDBC 2018). From May to December, sea surface conditions were in the acceptable temperature range (Figure 4). The daily mean of significant wave height was generally less than 3 m, with higher variations during the winter months (Figure 5). Using the FV-COM (Finite Volume Coastal Ocean Model) (Chen et al. 2011) data, bottom and surface current speed and direction were examined and were well below the specified engineering thresholds. Surficial sediment data were obtained and used to determine compatibility with cage engineering needs (Figure 6, Table 6). There were no interactions in the AOI with shipping fairways, wrecks and obstructions, unexploded ordnances, warning areas (e.g. Special Use Air Space), submarine transit lanes, ocean disposal sites, anchorage areas, pilot boarding areas, wind energy areas (planning or leased), or submerged aquatic vegetation.

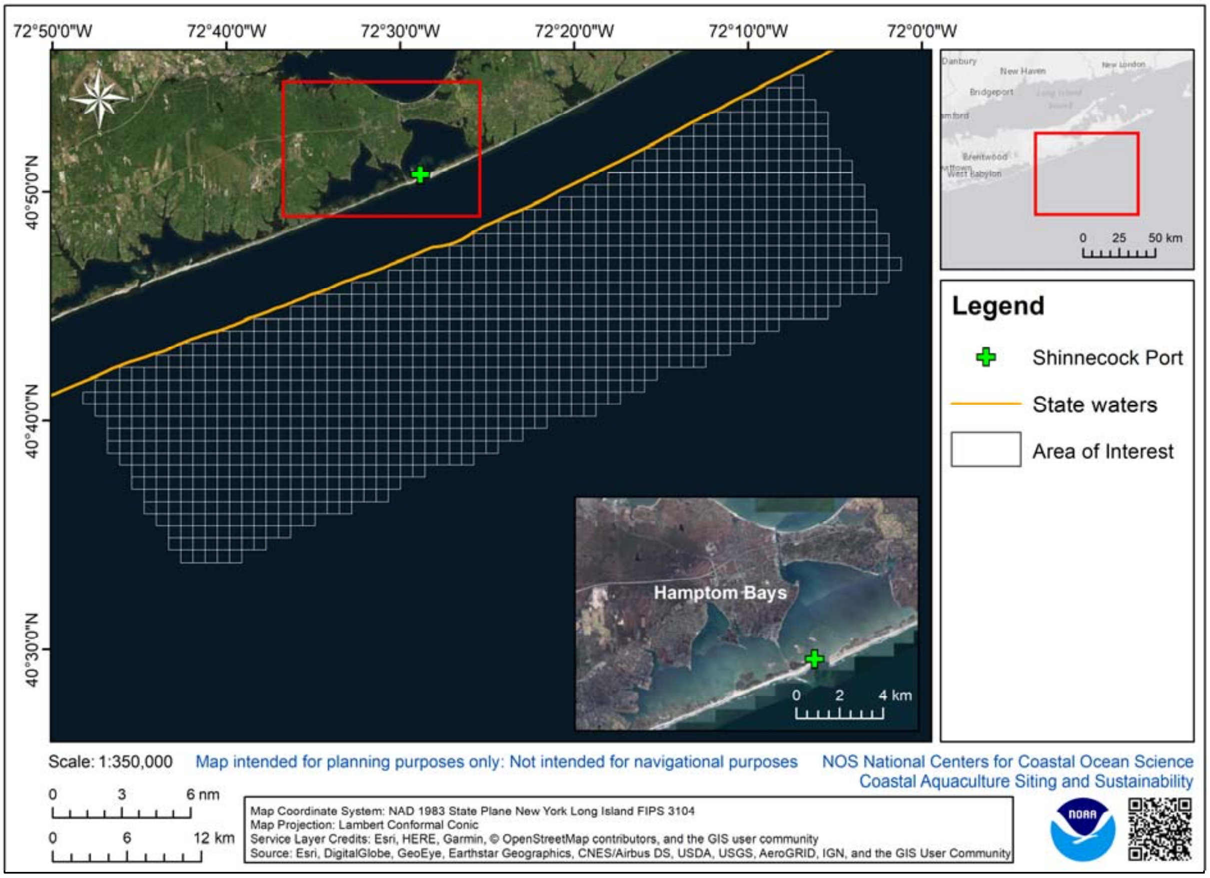


Figure 2. Aerial imagery of Sinnecock Port, New York, depicted as a green cross, in Suffolk County, New York. An Area of Interest (AOI) grid was generated, grid cell area of 0.375 mi^2, for the federal waters near Shinnecock Port for alternative siting analysis. Cell size based on farm footprint size of 1.5 mi^2, for analytical purposes farm footprint divided into four grid cells. For the analysis, we determined three alternative aquaculture sites (i.e. three groups of four cells).

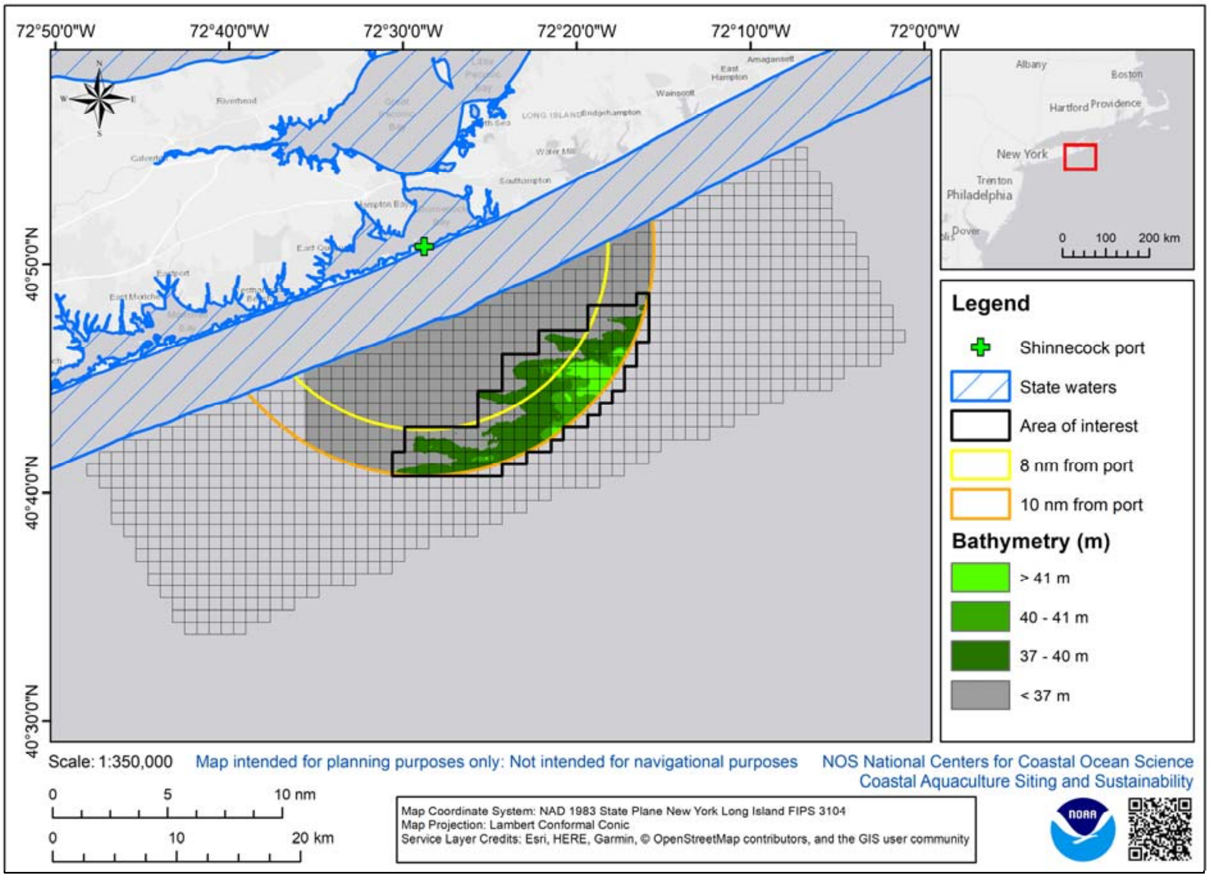


Figure 3. The original Area of Interest (AOI) grid cells were further refined (i.e. clipped) based on farm parameters and engineering specifications and needs of cage design. These include depth and distance from port. Depth was defined using a Digital Elevation Model (DEM) with a 10 m spatial resolution (Eakins et al 2009). Distance from port set at ≤ 8 nm from the port and ≤ 8 nm from the shoreline, as defined by the applicants.

Table 3. Scoring schema for distance and mean depth.

Data Layer	Category	Score	Rationale
Distance	≤ 8 nm	1	Telecommunication, Gas, time
	> 8 nm	0.25	Spotty Telecommunication, Gas, time
Mean depth	40 – 41 m	1	Ideal depth for equipment
	37 – 40 m	0.5	Shallower than ideal depth
	41 – 50 m	0.5	Deeper than ideal needed
	< 37 m	0	Too shallow for equipment

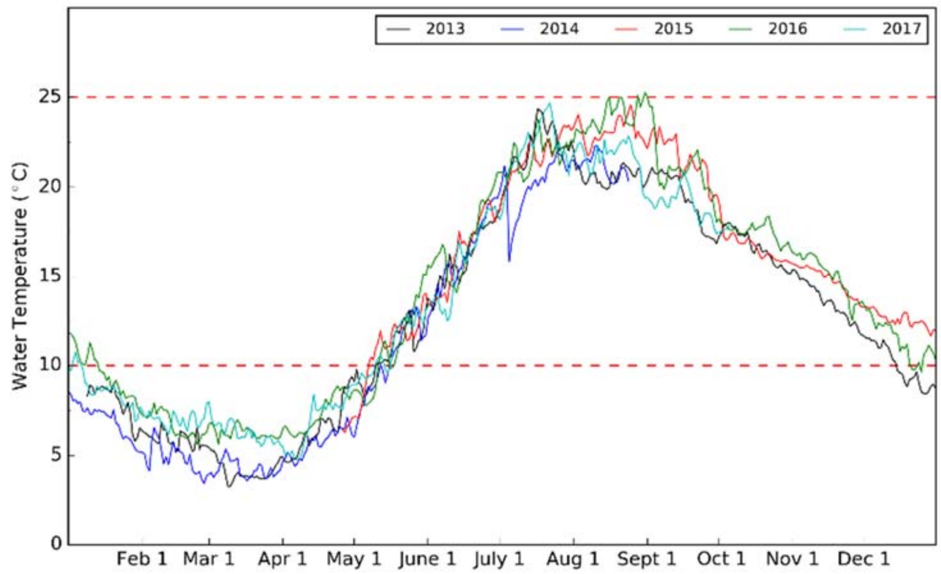


Figure 4. Daily mean of water temperature at 0.6 m depth from 2013 to 2017 at Montauk Point buoy (Station 44017, 40.693, -72.049). Area between red dotted lines are generally acceptable temperature ranges for grow out of striped bass or steelhead trout.

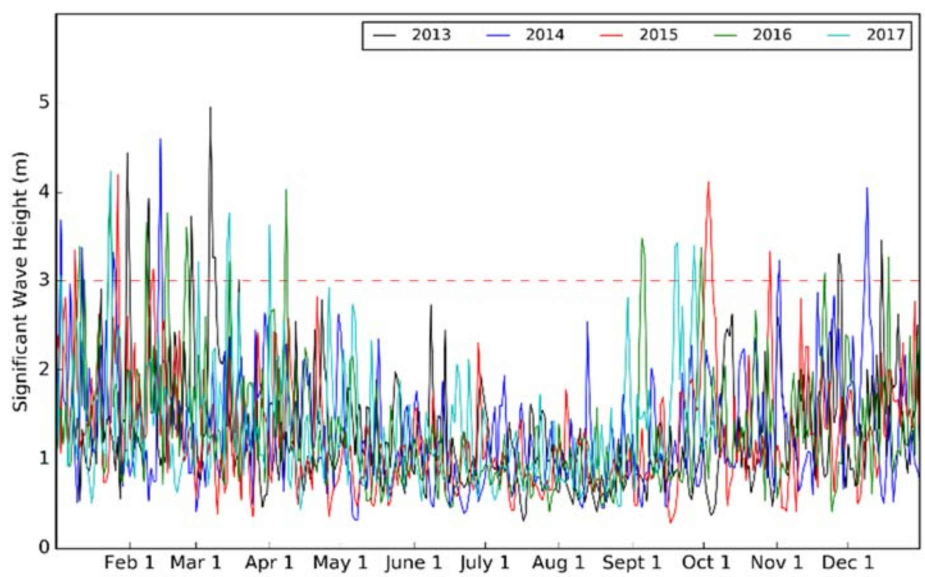


Figure 5. Daily means significant wave height from 2013 to 2017 at Montauk Point buoy (Station 44017, 40.693, -72.049). Area below red dotted line indicates ideal wave heights for farm operation.

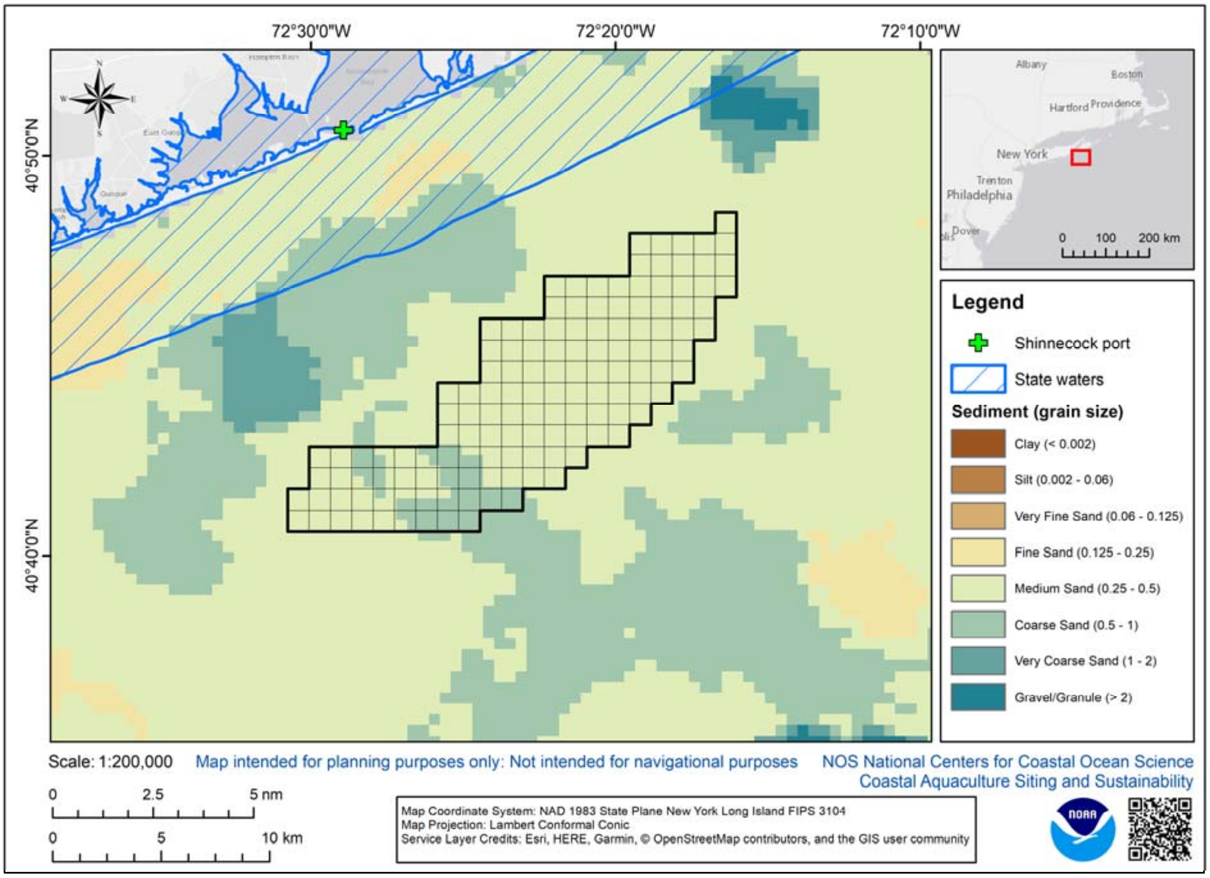


Figure 6. In 2017, The Nature Conservancy (TNC) used the USGS Sediment Texture Database to determine grain size at the 500 m spatial resolution. Soft sediments were derived from the USseabed database (USGS 2005) and sediment grain size was classified using the Wentworth (1922) scale. Kriging interpolation was used to create a continuous surface from the use of both databases. Classified into 8 classes: Clay (< 0.002): Silt (0.002 – 0.06): Very Fine Sand (0.06 – 0.125): Fine Sand (0.125 – 0.25): Medium Sand (0.25 – 0.5): Coarse Sand (0.5 – 1): Very Coarse Sand (1 – 2): Gravel/Granule (> 2).

Table 4: Scoring schema for surficial sediment based on farm requirements.

Data Layer	**Category**	**Score**	**Rationale**
Sediment grain size	< 2	1.0	Ideal sediment grain size for anchor
	≥ 2	0.2	Sediment grain size larger than ideal size for anchor

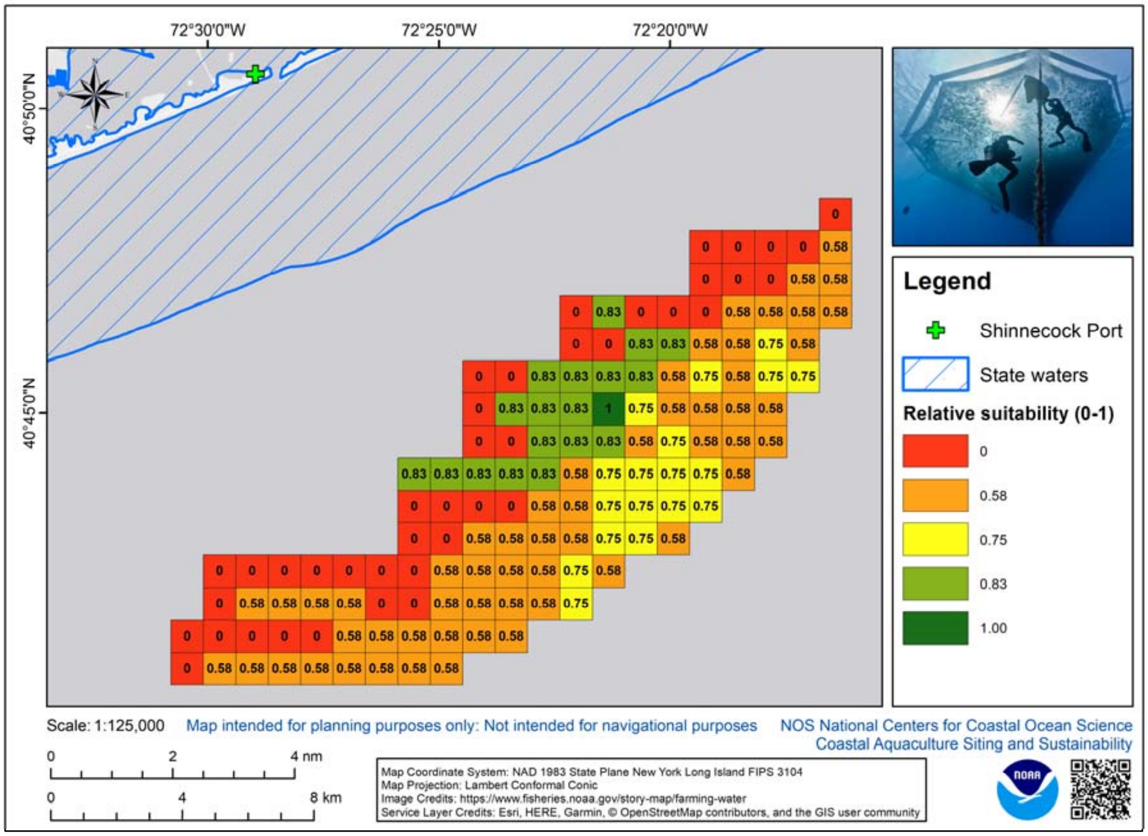


Figure 7. Relative suitability of three of the weighted farm parameters, mean depth, distance from port, and substrate. Ranges from 0 (Low suitability) to 1 (High suitability).

Farm Requirements Summary

After analysis of the farm requirements, most cells dropped into the moderate to low suitability categories. However, a grouping of cells in the middle of the AOI indicated higher suitability for the farm requirements. Here, suitable depths and distance to port were identified, with only one cell meeting the exact specifications. Farm requirement suitability was primarily driven by depth and distance to port. Due to the need to be less than 8 nm from the Shinnecock Port location, depths were largely too shallow for gear, and therefore lowered cell suitability scores closer to the shoreline. Similarly, because outer boundary cells (i.e., those greater than 8 nm from port) were too far from port, even though depth was sufficient, scores were still lowered.

Military

The US military operates, whether for national security or training operations, throughout US federal waters, out to the Economic Exclusion Zone (EEZ) and into high seas. National security is a top priority for the United States, and will most likely continue to be in the future. Off many US coastlines, there are military operating areas, installations, unexploded ordnances and formerly used defense sites (FUDS), and danger and restricted areas. South of Long Island, New York is the Narragansett Operating Complex, where a myriad of different military activities occur. Here, we take each area and the associated activities that occur within that area, to assess relative suitability.

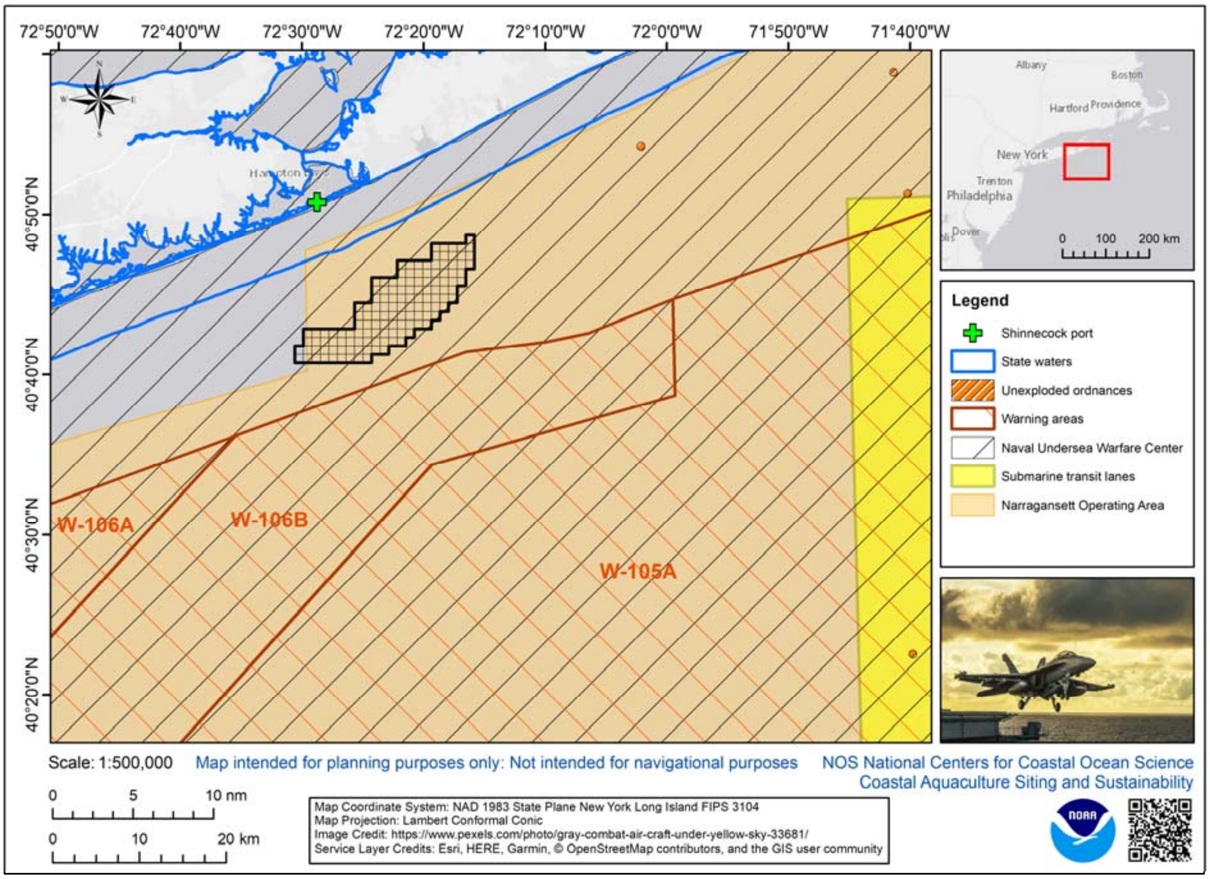


Figure 8. Military operations are the largest ocean space users inside the United States Exclusive Economic Zone (EEZ). Depicted with the AOI are the Naval Undersea Warfare center and Narragansett Operating Area both of which overlap the AOI (EIMS Data WIPT Team U.S. Fleet Forces, U.S. Navy, 2018). Other areas examined, include Military Danger and Restricted Areas**,** Submarine Transit Lanes, Special Use Airspace (W-105, W-106), and unexploded ordnances Please see https://www.northeastoceandata.org/data-download/ for more details.

Table 5. Scoring schema for Narragansett operating area

Data Layer	Category	Score	Rationale
Narraganset Operating Area	In	0.5	Inside operating area, increased coordination
	Out	1.0	Outside of operating area

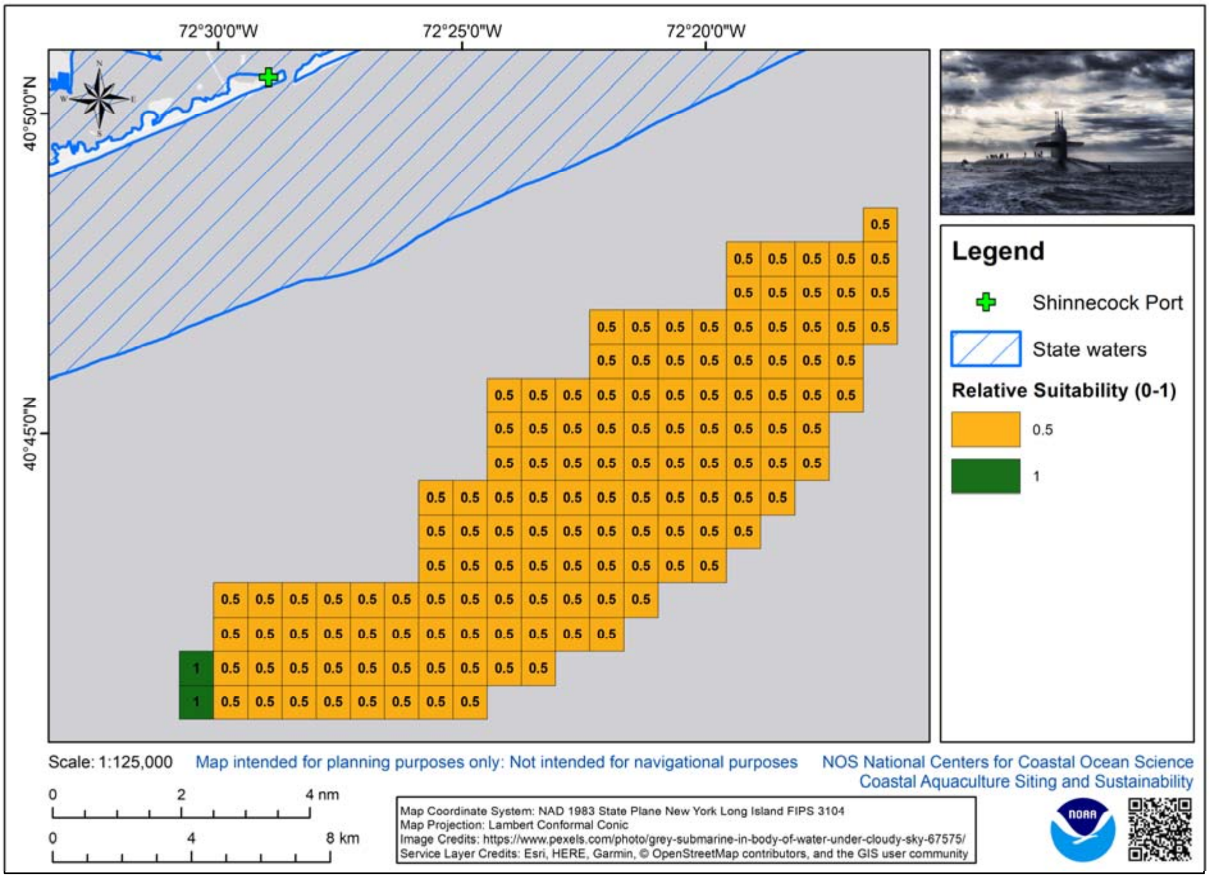


Figure 9. Relative suitability of military layers, the Narraganset operating area was the only military constraint used for the relative suitability analysis. Ranges from 0 (Low suitability) to 1 (High suitability).

Military Requirements Summary

All of the AOI, with the exception of two cells on the far west side, are inside the Narragansett Operating Complex (Figure 8). However, none of the cells overlapped with unexploded ordnance, W-105, W-106, or submarine transit lanes. Therefore, the relative suitability score for those cells in the Operating Areas were given a score of 0.5, as further discussions need to occur to completely rule out the area. As Wind Planning Areas currently overlap with the Operating Complex and compatibility has been assessed, aquaculture operations may pose no significant interference with military operations in the AOI.

Navigation

All cells are located in a Navigation Safety and Security area (Figure 10). Additionally a Submarine Cable goes through a portion of the AOI (Figure 10, Table 6). A 500 m protective area was established on each side of submarine cable, as these cables are responsible for an immense amount of national and international communications. A defined, exact location may not always be available for submarine cables at any one point, and therefore require conservative estimates and increased care and logistics to ensure no interactions occur between aquaculture operations and the submarine cables.

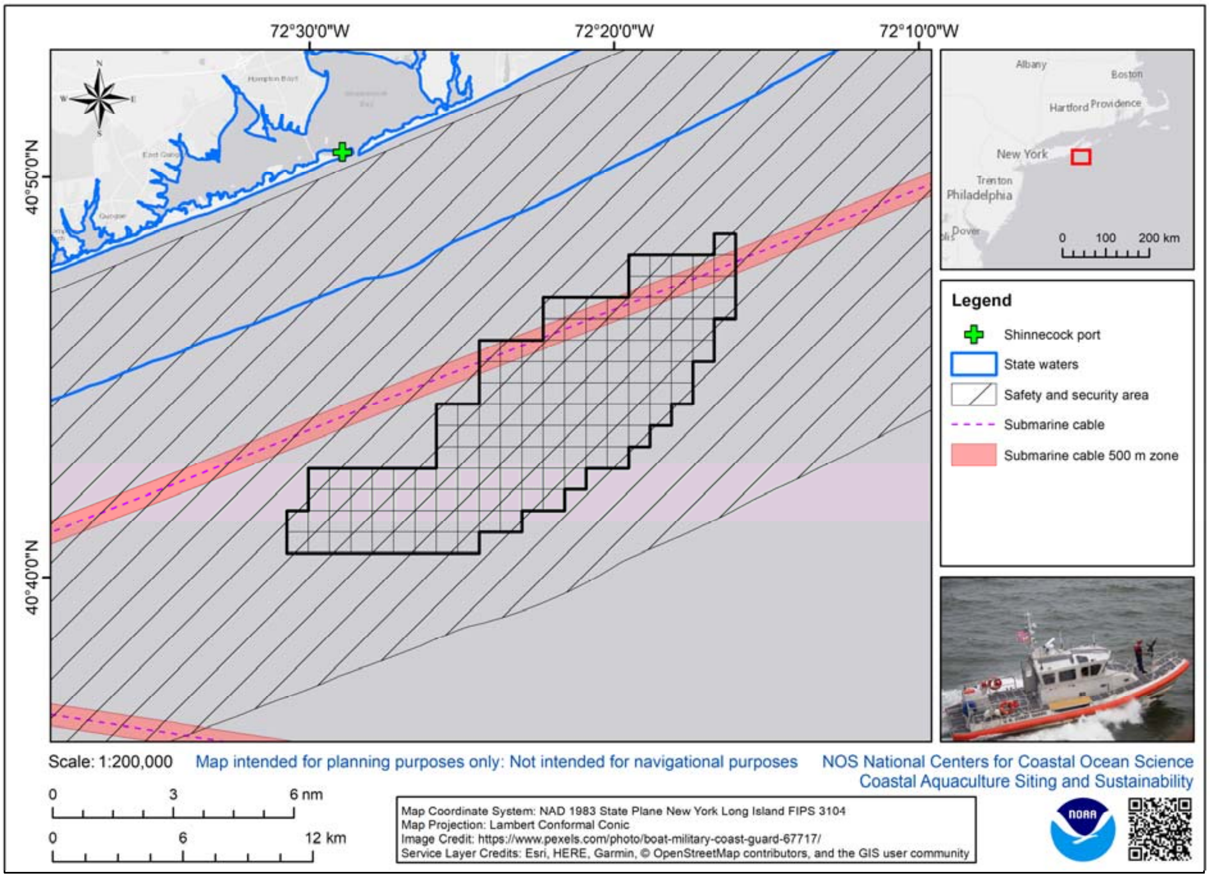


Figure 10. Navigational Chart Safety and Security areas and submarine cables overlapping with the AOI (NOAA OCM 2018).

Table 6: Submarine cable categories, score, and rationale for scoring.

Data Layer	Category	Score	Rationale
Submarine Cable	Intersects cable	0	High risk of cable interference
	≤ 500 m from cable	0.5	Moderate risk of cable interference
	> 500 m from cable	1.0	No risk of cable interference

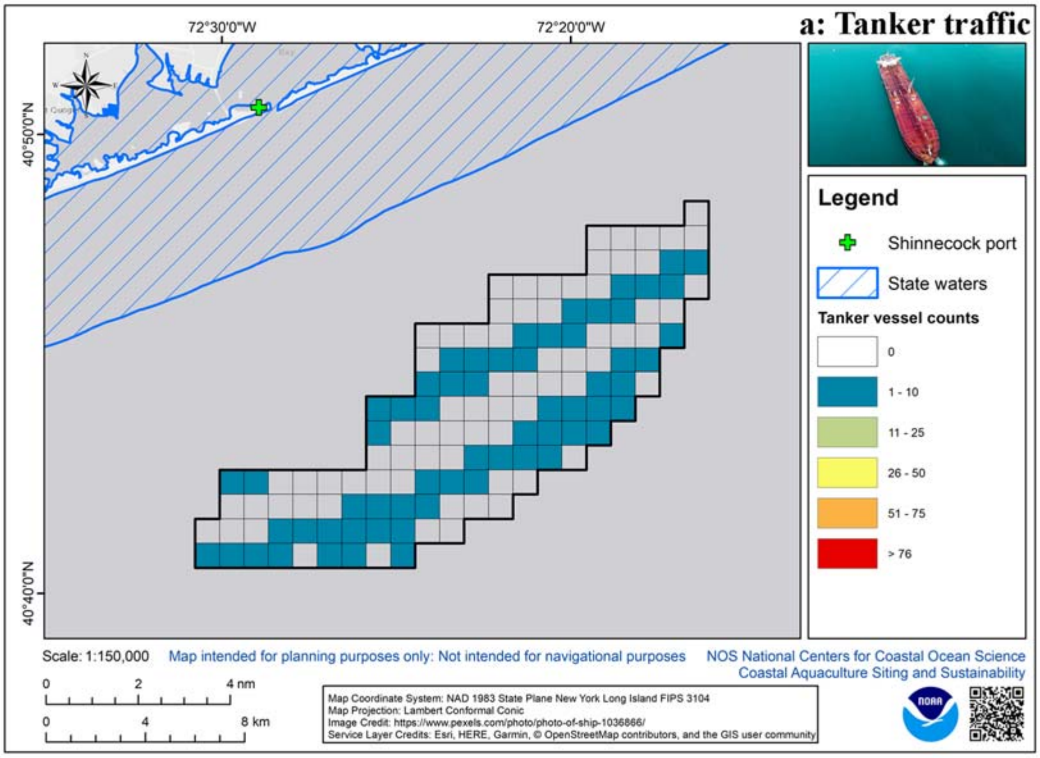
Automatic Identification System (AIS) Classification Breakdown

As previously mentioned, AIS data are information collected by the U.S. Coast Guard to monitor real-time vessel information to improve navigation safety. Data such as ship name, purpose, course, and speed are acquired 24 hours per day. Tanker and cargo traffic are larger constraints for aquaculture siting than pleasure craft, as the maneuverability and charted routes of larger vessels are more difficult to alter to accommodate a farm. Here, we accounted for this in the analysis by giving scores that are more conservative for those vessel types (Table 7). For more information on AIS, visit the Nationwide Automatic Identification System website.

Table 9. Automatic Identification System (AIS) classification schema and scores.

Vessel Types+	Vessel Counts /Year	Score	Rationale
Cargo or Tanker	0	1	No vessel interactions
Example: Oil tanker	1-10	0.8	Extremely low vessel interactions
	11-25	0.5	Low vessel interactions
	26-50	0.4	Moderate vessel interactions
	51-75	0.2	High vessel interactions
	>76	0.1	Extremely high vessel interactions
Tug and Tow	0	1	No vessel interactions
Example: Tug boat	1-10	0.8	Extremely low vessel interactions
	11-25	0.7	Low vessel interactions
	26-50	0.5	Moderate vessel interactions
	51-75	0.2	High vessel interactions
	>76	0.1	Extremely high vessel interactions
Passenger	0	1	No vessel interactions
Example: Cruise ship	1-10	0.9	Extremely low vessel interactions
	11-25	0.8	Low vessel interactions
	26-50	0.6	Moderate vessel interactions
	51-75	0.4	High vessel interactions
	>76	0.2	Extremely high vessel interactions
Fishing	0	1	No vessel interactions
Example: Shrimp	1-10	0.9	Extremely low vessel interactions
boat	11-25	0.8	Low vessel interactions
	26-50	0.6	Moderate vessel interactions
	51-75	0.3	High vessel interactions
	>76	0.1	Extremely high vessel interactions
Pleasure and Unknown	0	1	No vessel interactions
Example: Sail boat	1-10	1	Extremely low vessel interactions
Police boat	11-25	1	Low vessel interactions
	26-50	0.9	Moderate vessel interactions
	51-75	0.7	High vessel interactions
	>76	0.5	Extremely high vessel interactions

+Vessel types based BOEM AIS document (https://marinecadastre.gov/ais/AIS%20Documents/Tutorial_How_to_Build_Vessel_Density_Maps_with_AIS_OCM508.pdf -)



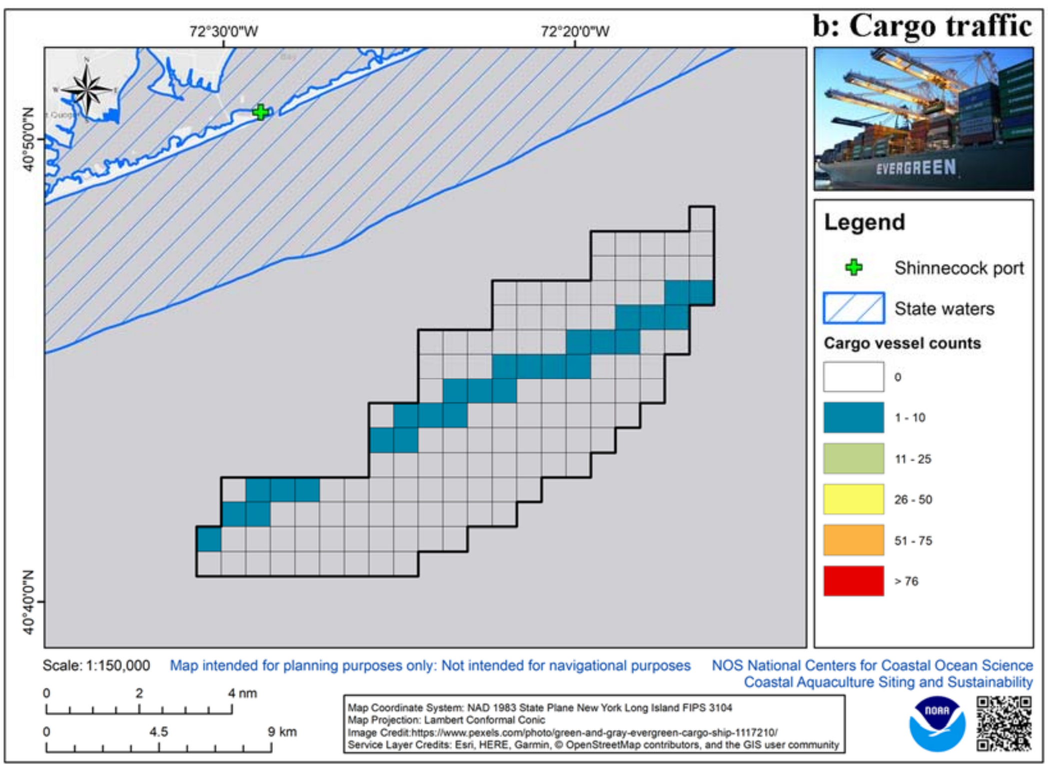
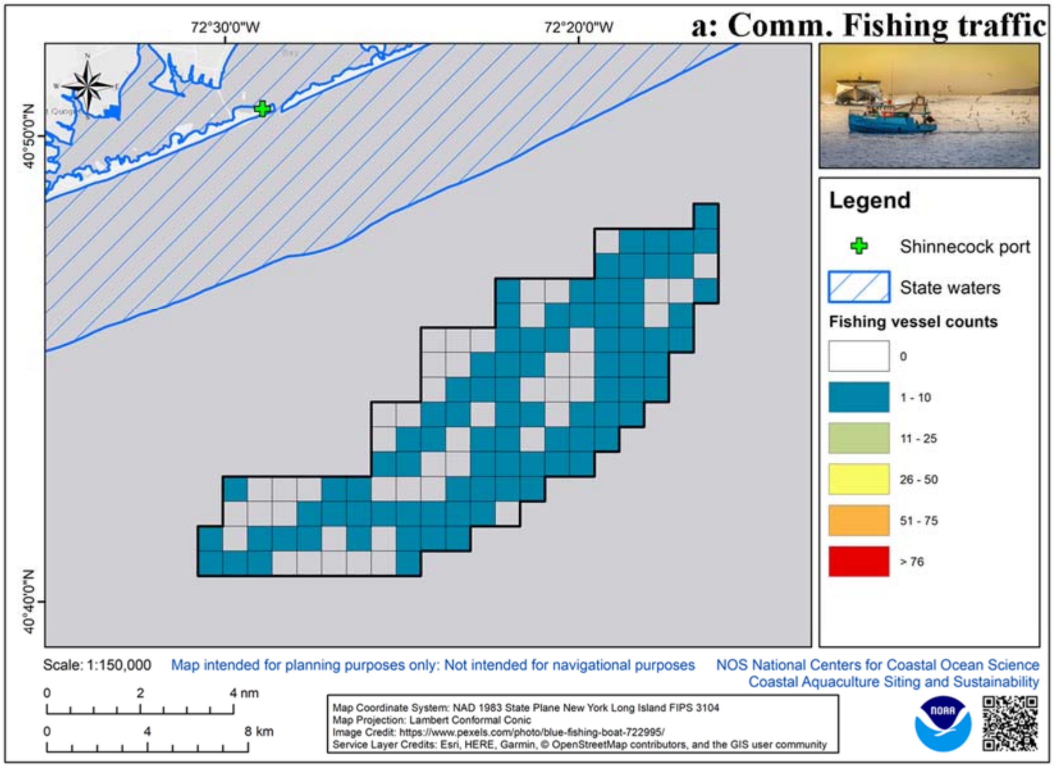


Figure 11. Automatic Identification System (AIS) 2014 annual Cargo and Tanker vessel counts for each grid cell or the number of times a vessel passed through the grid cell. Data are generated VHS signals from moving vessels, unique vessel codes are used to classify ships and density and counts are derived from data (Marine Cadastre 2018).



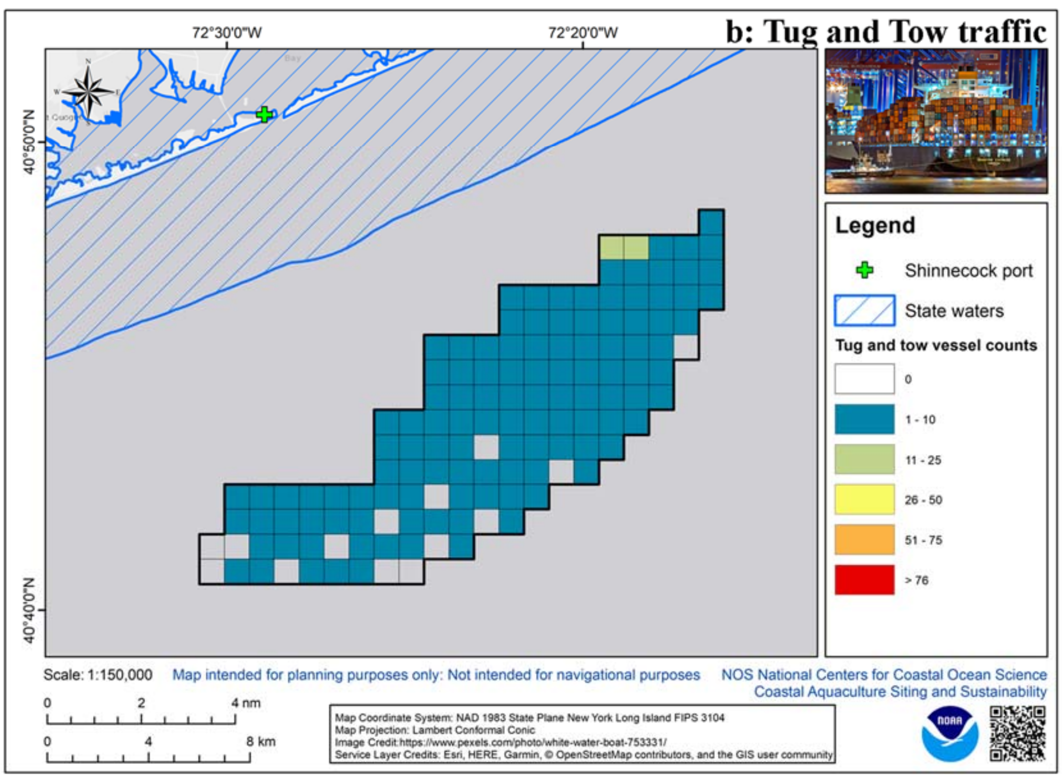
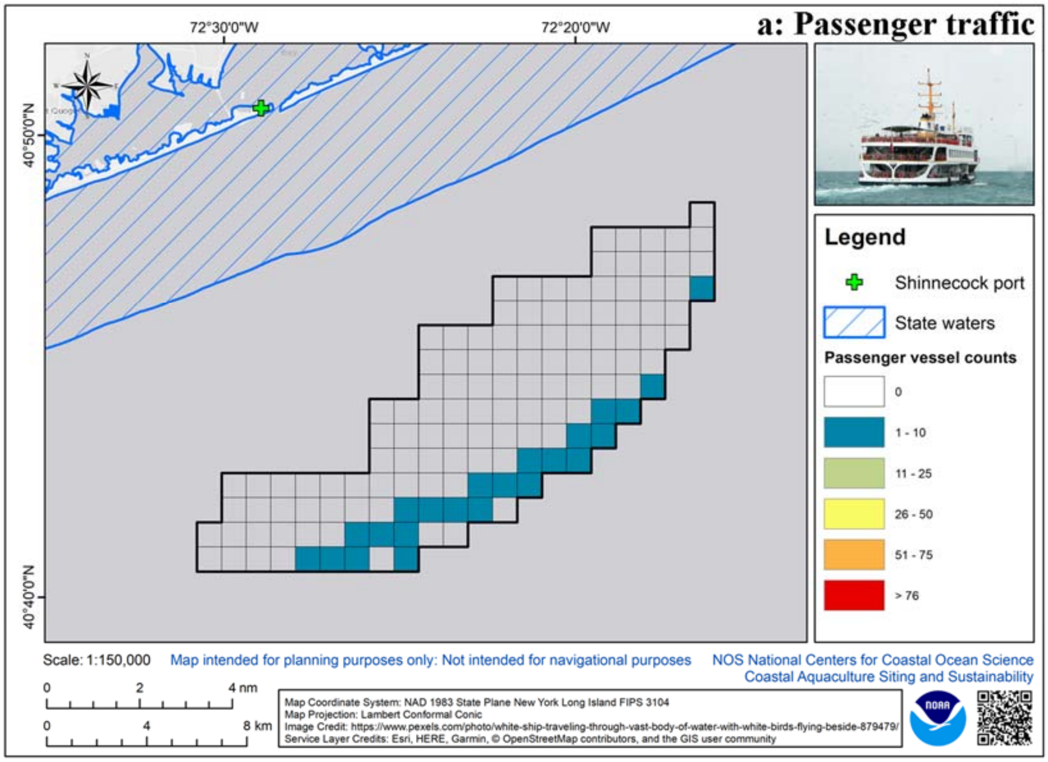


Figure 12. Automatic Identification System (AIS) 2014 annual Commercial Fishing and Tug and Tow counts for each grid cell or the number of times a vessel passed through the grid cell. Data are generated VHS signals from moving vessels, unique vessel codes are used to classify ships and density and counts are derived from data (Marine Cadastre 2018).



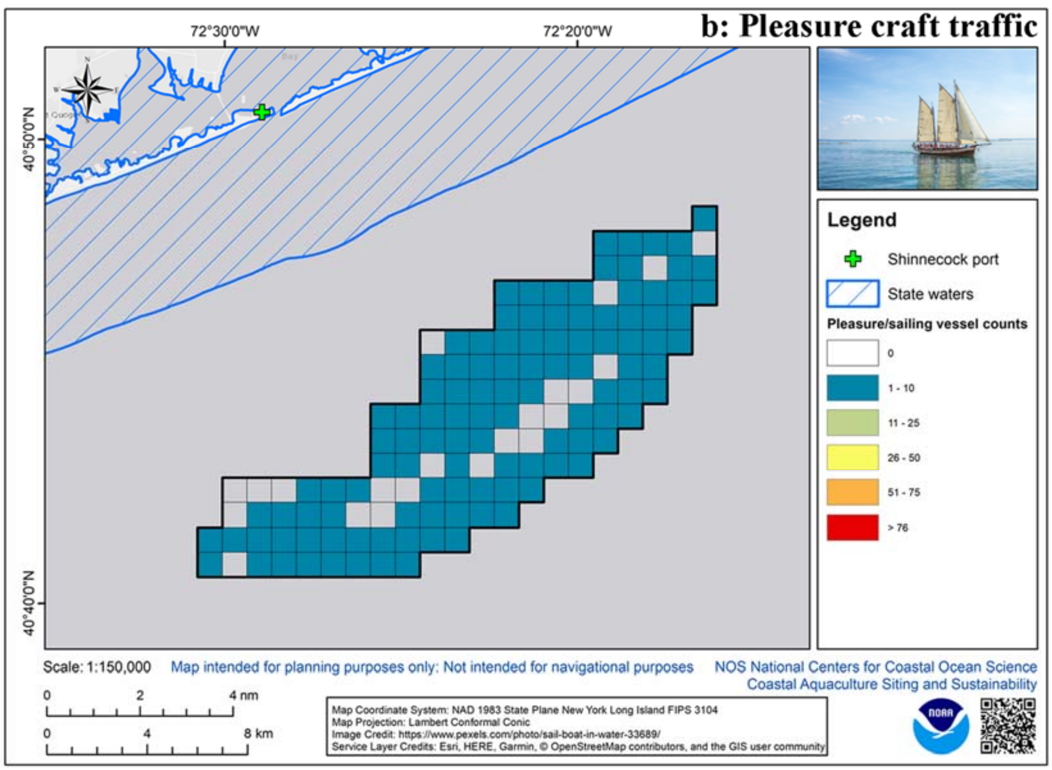


Figure 13. Automatic Identification System (AIS) 2014 annual for Passenger vessels and Pleasure or Sailing vessel counts for each grid cell (i.e., the number of times a vessel passed through the grid cell). Data are generated from VHS signals from moving vessels, and unique vessel codes are used to classify vessel density and counts (Marine Cadastre 2018).

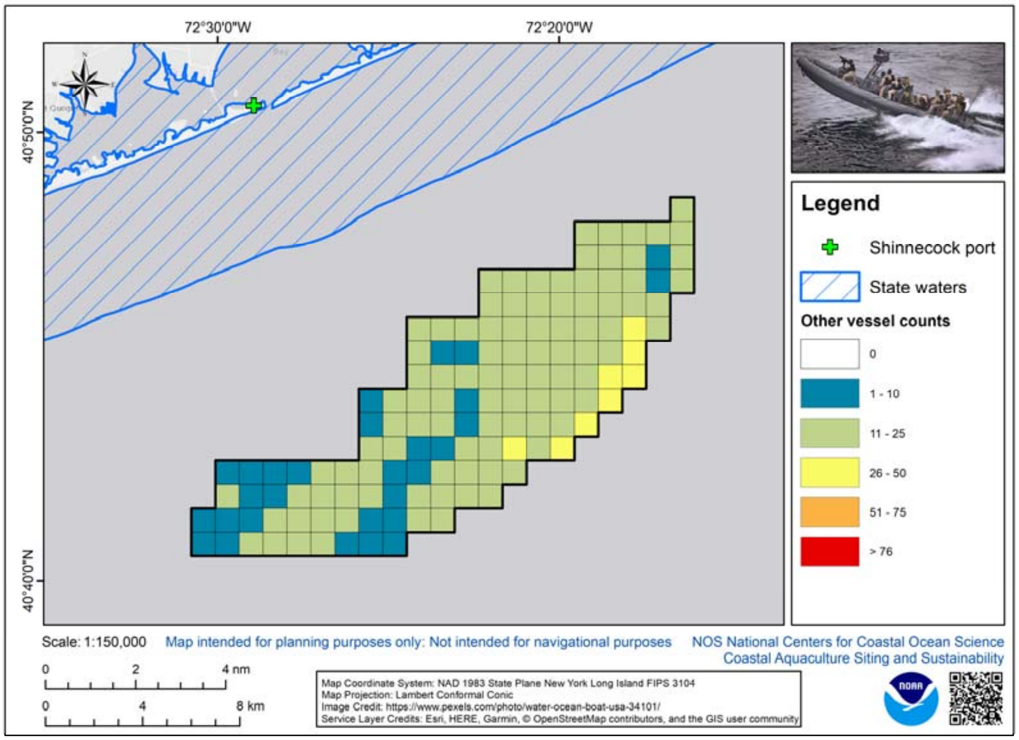


Figure 14. Automatic Identification System (AIS) 2014 annual "Other" vessel counts for each grid cell or the number of times a vessel passed through the grid cell. Data are generated VHS signals from moving vessels, unique vessel codes are used to classify ships and density and counts are derived from data (Marine Cadastre 2018).

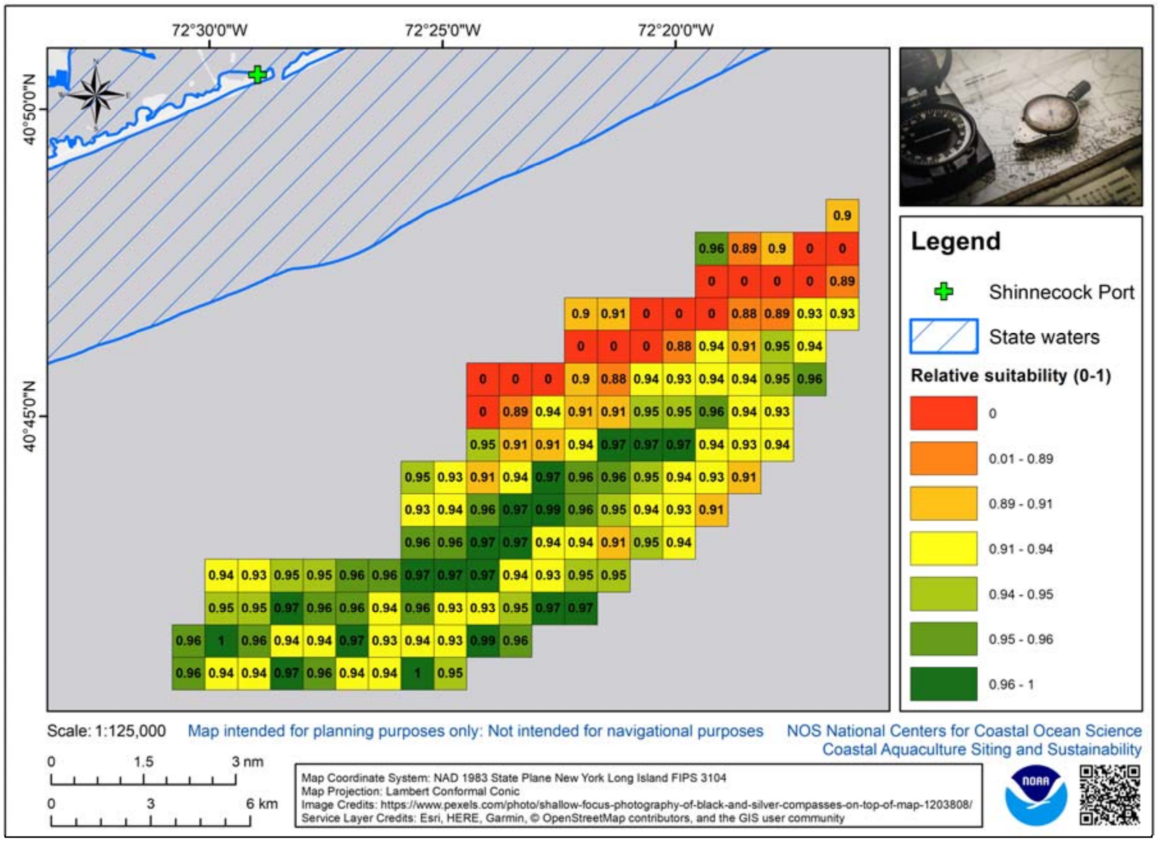


Figure 15. Relative suitability of navigational layers, including submarine cables and annual summaries Automatic Identification System (AIS) vessel interactions. Ranges from 0 (Low suitability) to 1 (High suitability).

Navigation Requirements Summary

The submarine cable in the northern portion of the AOI created a number of unsuitable cells. All of the AOI in within the safety and security area (Figure 10). When looking at the AIS data among the various vessel types, the “other vessel” traffic (Table 7, Figures 11 -14) showed the highest interaction of vessel type categories, however only a few cells were in the 26-50 vessel interactions per year category (Figure 14). Other vessels include port tenders, anti-pollution equipment, high-speed crafts, Pilot vessels, search and rescue, Wing in ground, dredging or underwater operations, diving operations, law enforcement, Spare – for assignment to local vessel, medical transport, mobile offshore drilling units, offshore supply, oil recovery, industrial vessels, and ships according to the RR Resolution No. 18 (Marine Cadastre, 2018). Due to the numerous different vessel types included in the other category, it is no surprise that this category has the most vessel traffic in the AOI, and lowered scoring in cells with heavier traffic accordingly. Notably, all vessel traffic is relatively low in the entire AOI.

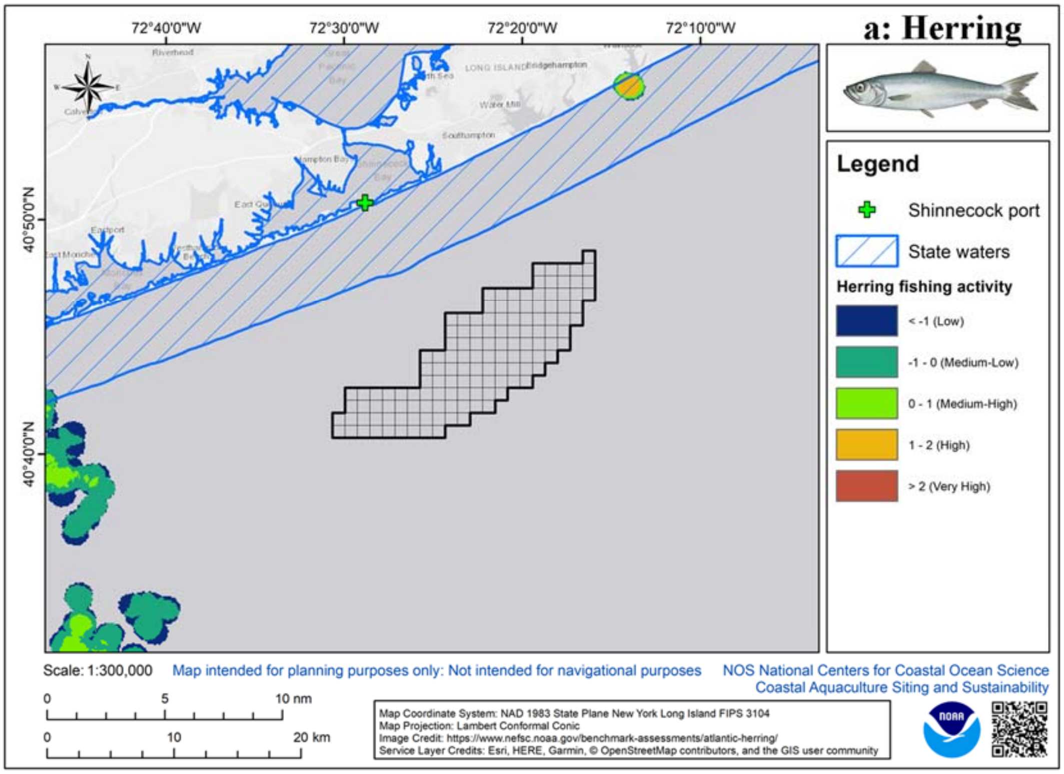
Industry and Recreation

Fisheries Activity and Abundance

Commercial fishing activity data was obtained from VMS tracking systems for the 2015 – 2016 seasons. These data were generalized to maintain the anonymity of the fishing vessels, and allows general patterns to be deduced. VMS data is subject to strict confidentiality restrictions. The process of removing sensitive vessel locations followed the "rule of three" mandated by NMFS Office of Law Enforcement (OLE) by utilizing a screening grid to identify grid cells containing three or more VMS records. VMS records within cells that contain fewer than three VMS records were not included in the analysis. A statistical method to normalize data was used on the subsequent density grids and data values represent standard deviations (NEOD 2018). One caveat is there is no distinction among vessel transit, fishing activity type, or other vessel activities. For data we did use, the vessel was traveling less than four to five knots, as this is most likely when the fishing occurred. Scoring of fishing activity followed the categories determined by the data originators.

Table 8: Commercial fishing activity scoring schema.

Data Layer	Category	Score	Rationale
Commercial fishing	Low	1	Low interference with fishing activity
	Mod low	0.9	Moderately low interference with fishing activity
	Mod high	0.7	Moderately high interference with fishing activity
	High	0.5	High interference with fishing activity
	Very high	0.2	Very high interference with fishing activity



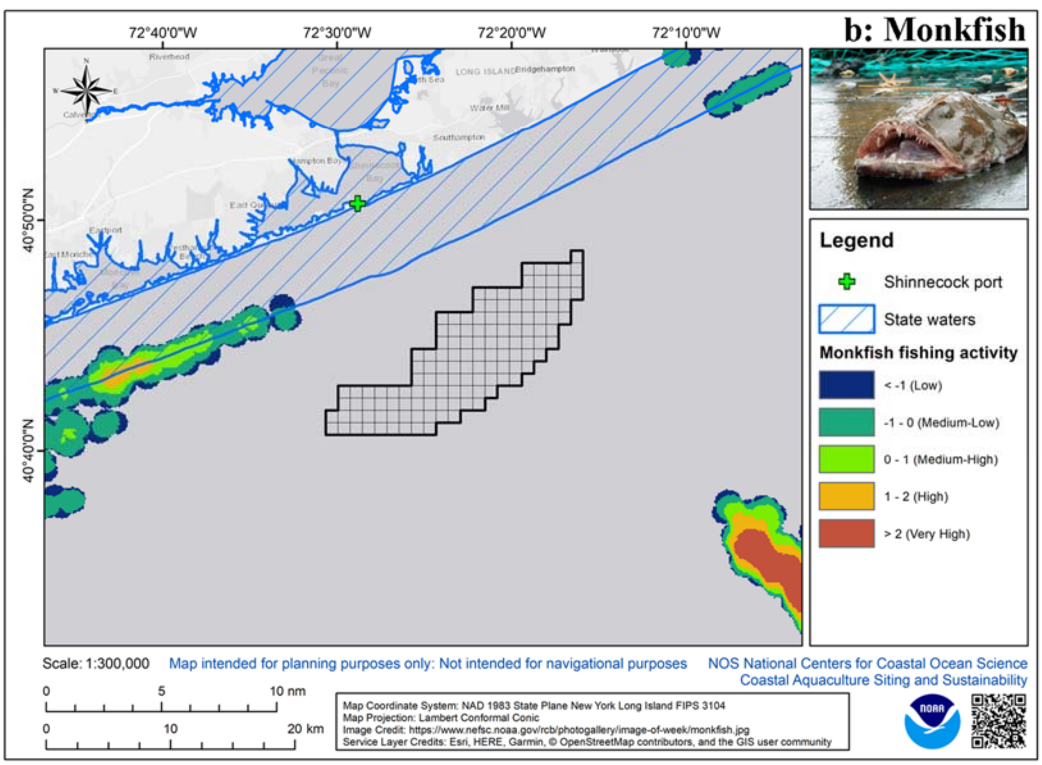
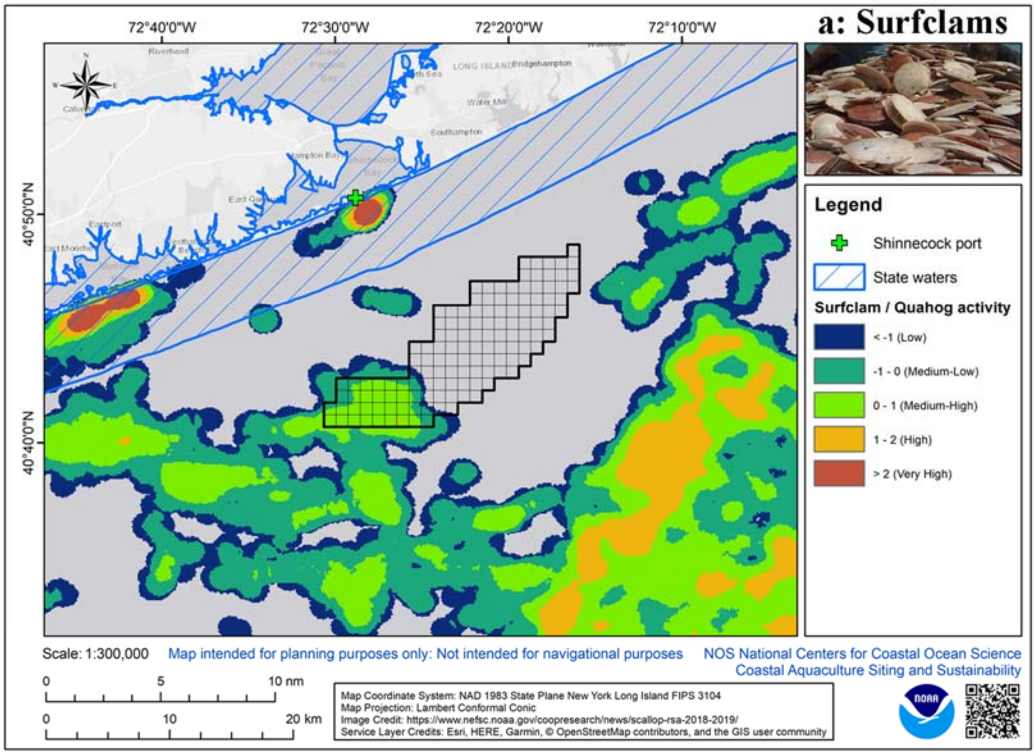


Figure 16. Herring and Monkfish Commercial Fishing Activity 2015 to 2016 (VMS data - Fontenault 2018).



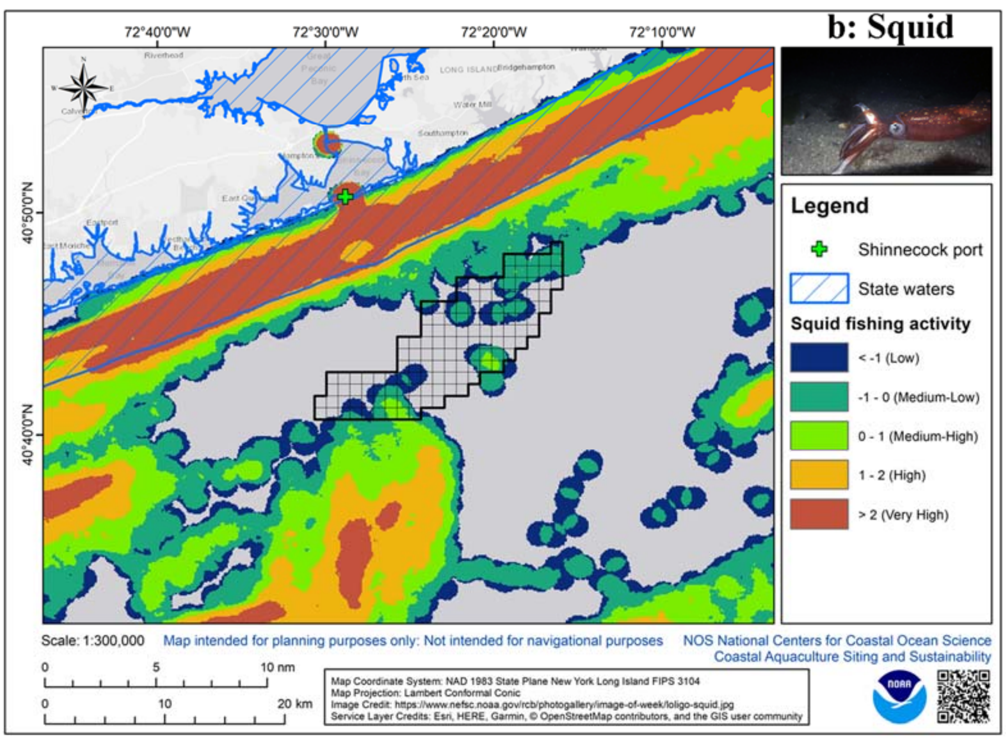


Figure 17. Quahog (i.e., Surfclams) and Squid Commercial Fishing Activity 2015 to 2016 (VMS data - Fontenault 2018).

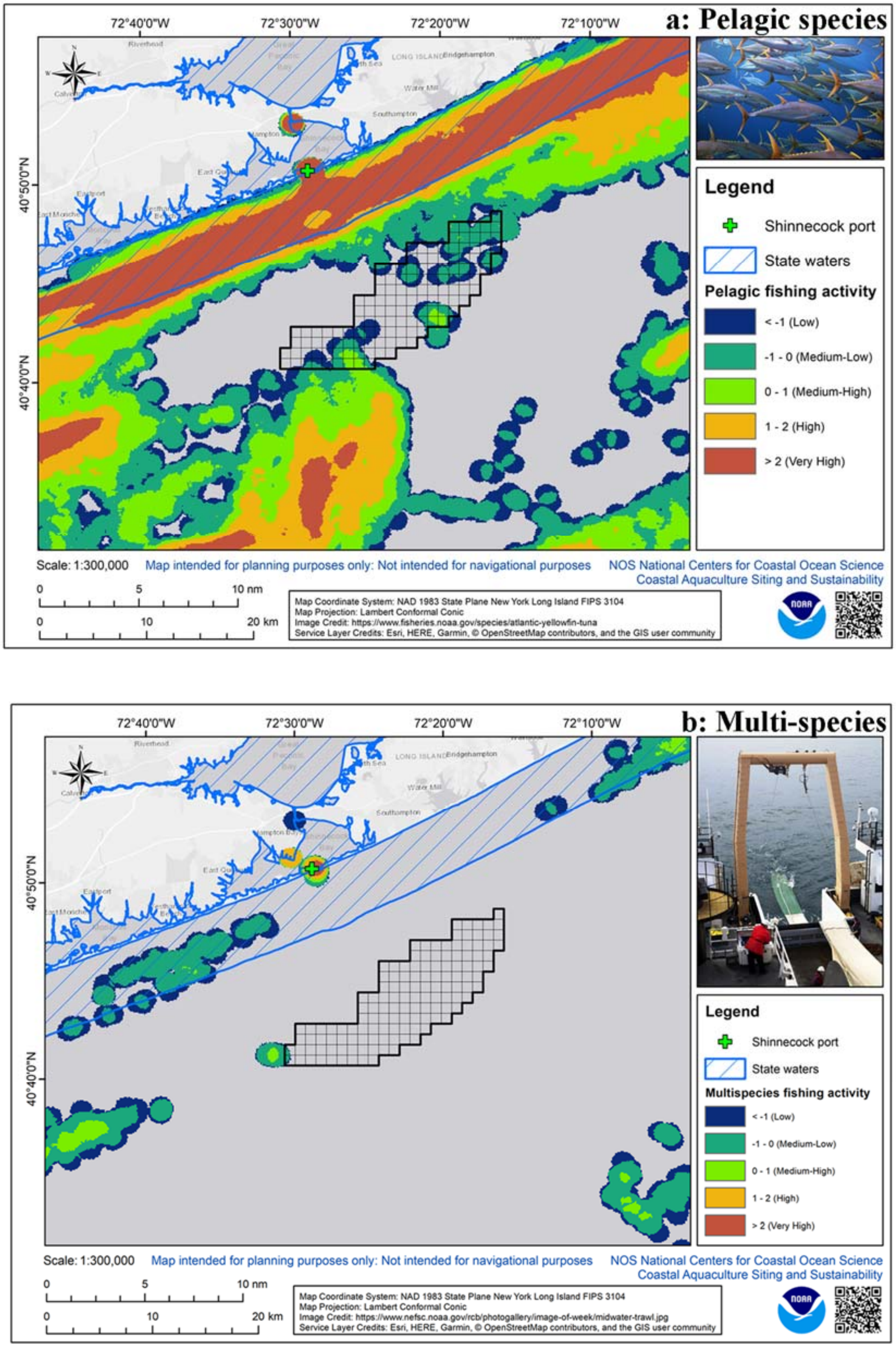


Figure 18. Pelagic and multispecies Commercial Fishing Activity 2015 to 2016 (VMS data - Fontenault 2018).

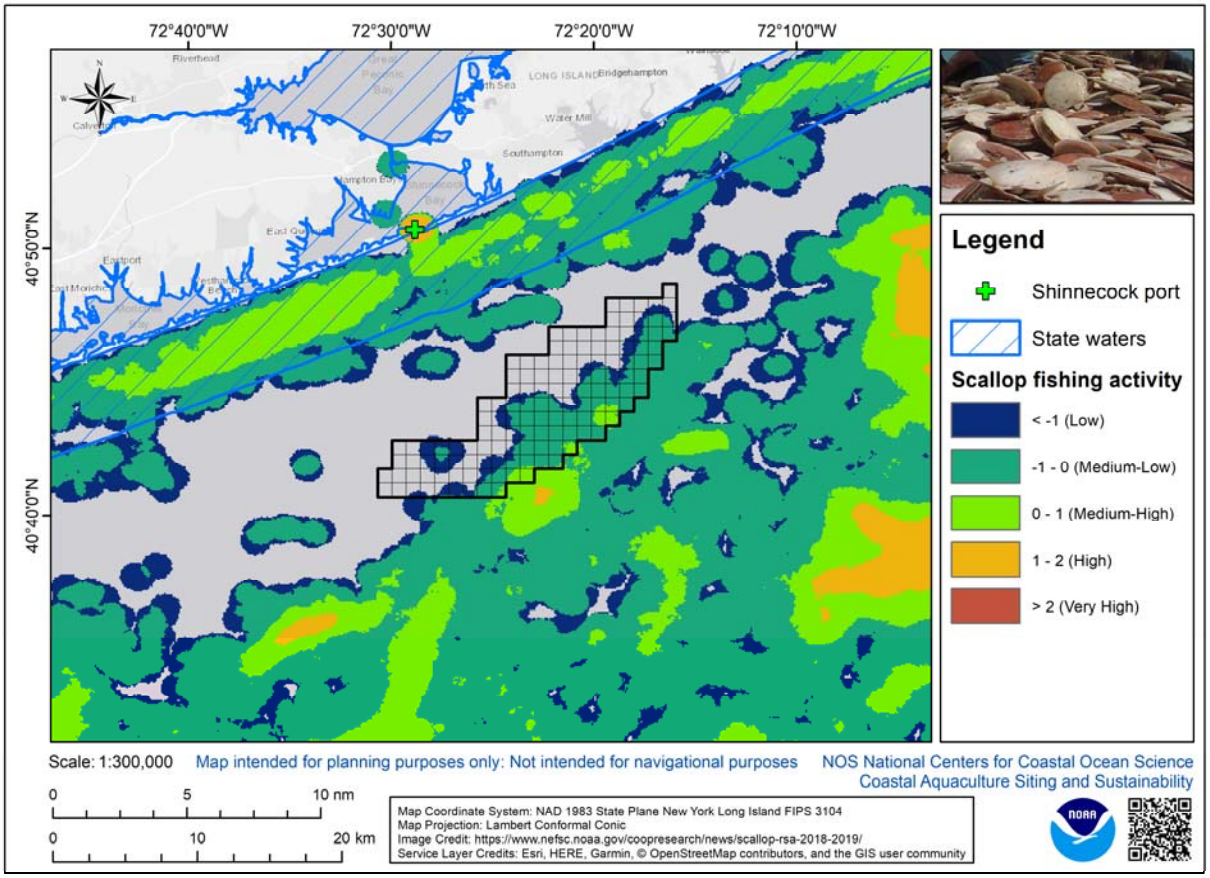


Figure 19. Scallop Commercial Fishing Activity 2015 to 2016 (VMS data - Fontenault 2018).

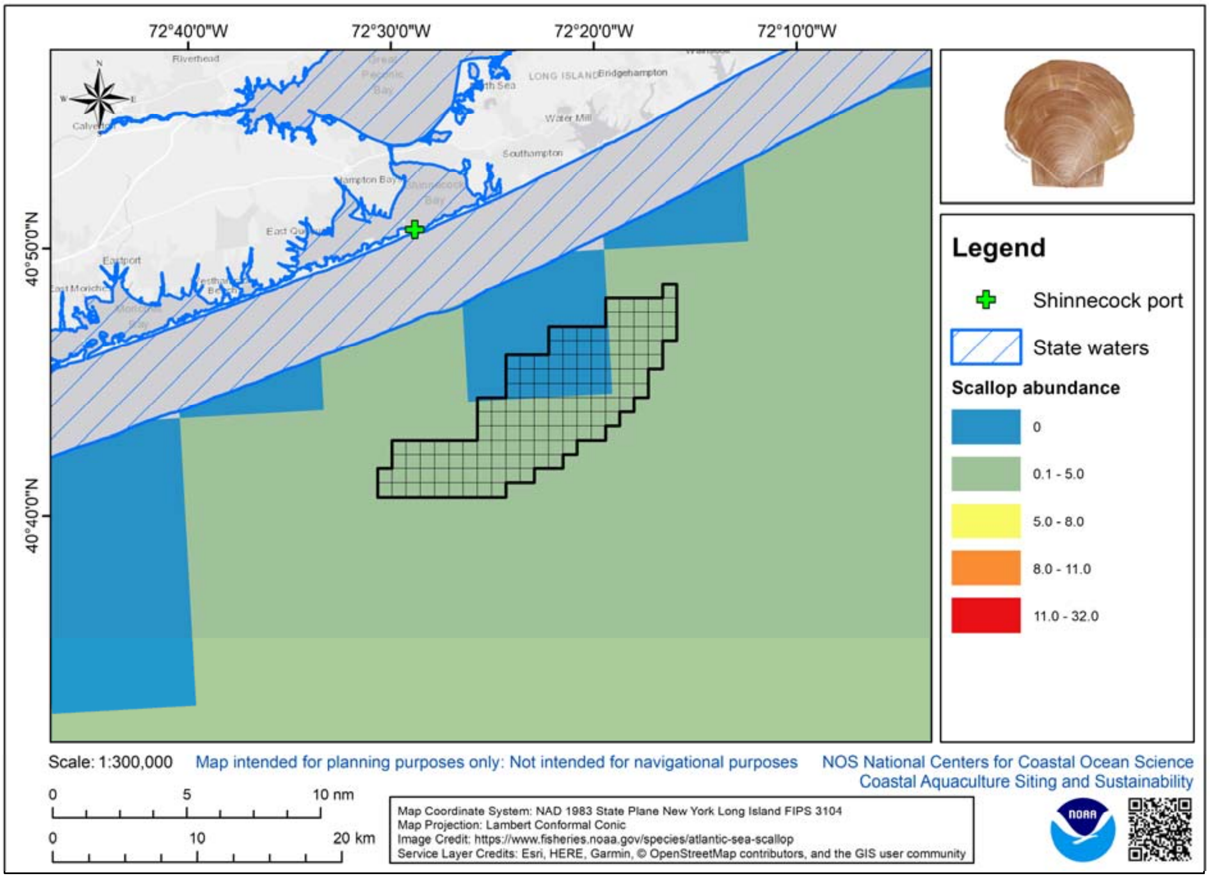


Figure 20. Scallop average abundance of scallops from 2003-2012 Swept Area Seabed Impact (SASI) model using video survey data from the School of Marine Science and Technology (SMAST) University of Massachusetts Dartmouth. Average abundances classified into 5 classes using the percentile rankings (<16%, 16 - 84%, 84 - 97.7%, 97.7 - 99.9%, >99.9%) (SMAST 2016).

Table 9. Scoring schema for scallop abundance data.

Data Layer	Category	Score	Rationale
Scallop abundance	0	1	No scallops detected in survey
	0 - 4	0.9	Very low scallop abundance
	5 - 7	0.7	Low scallop abundance
	8 - 10	0.5	High scallop abundance
	11 - 32	0.2	Very high scallop abundance

http://easterndivision.s3.amazonaws.com/Marine/MooreGrant/AveragePresenceAbundanceSMAST.pdf

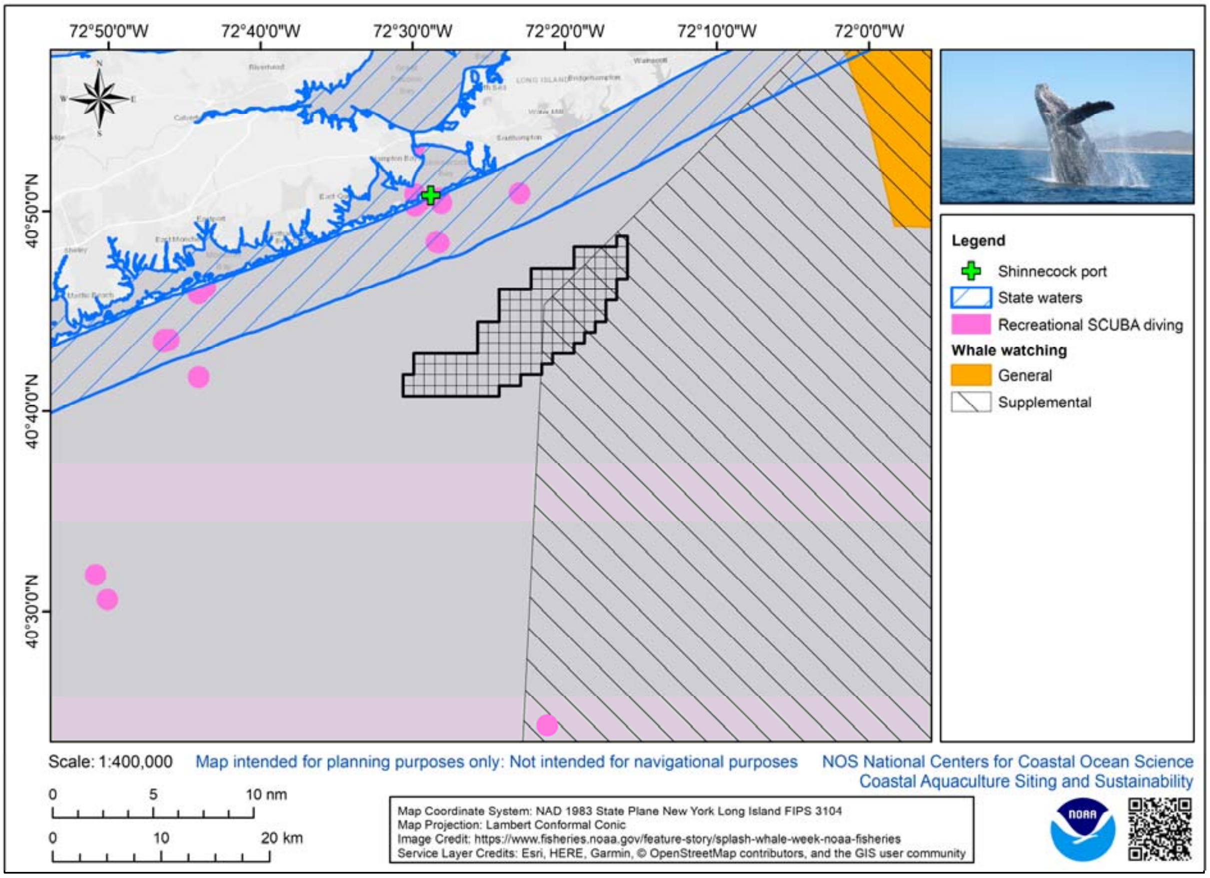


Figure 21. Recreational SCUBA diving areas and commercial whale watching areas. Available from http://archive.neoceanplanning.org/wp-content/uploads/2015/10/Recreation-Study_Final-Report.pdf. Retrieved on July 20 2018.

Table 10. Scoring schema for recreational layers.

Data Layer	Category	Score	Rationale
SCUBA Diving	In	0.75	https://www.northeastoceandata.org/files/metadata/Themes/Recreation/RecreationalSCUBADivingAreas.pdf
	Out	1	
Whale Watching	In	0.75	https://www.northeastoceandata.org/files/metadata/Themes/Recreation/CommercialWhaleWatchingAreas.pdf
	Out	1	

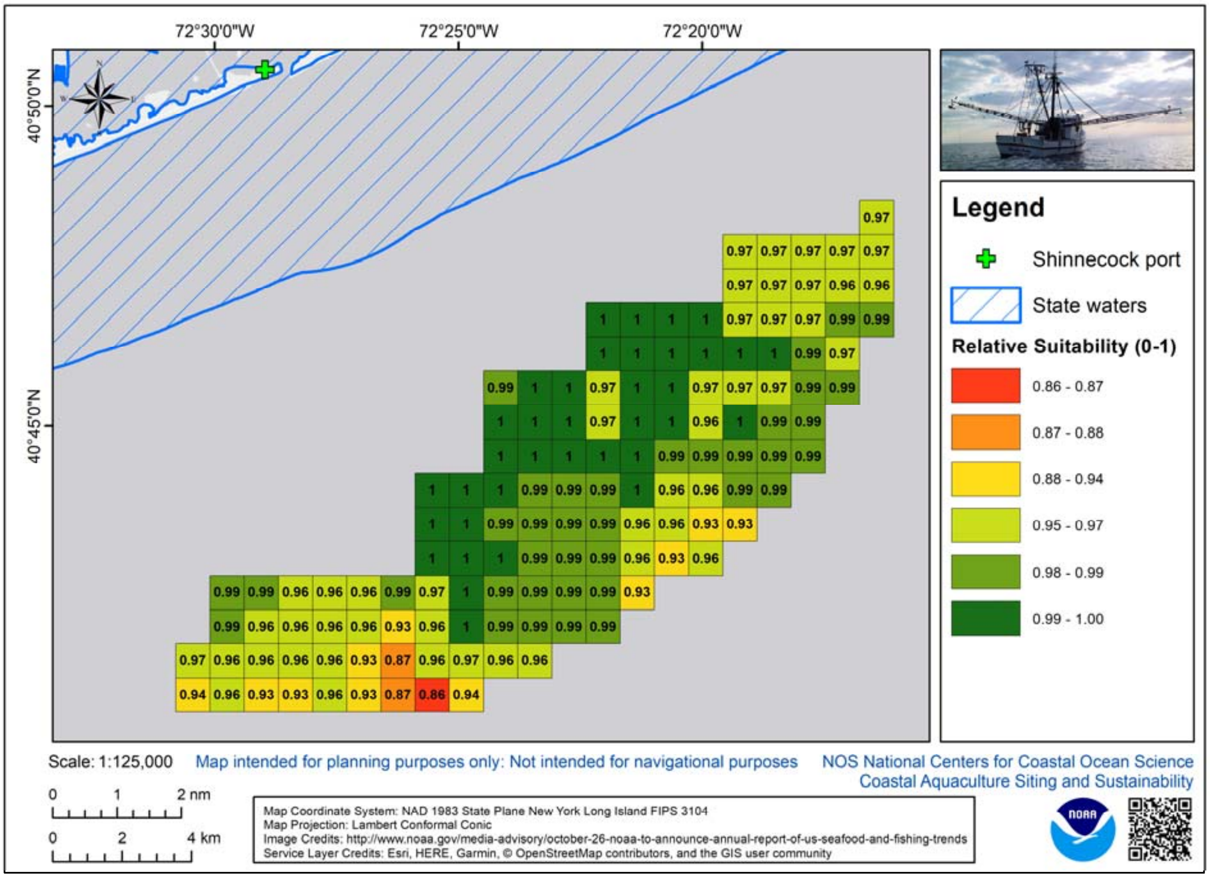


Figure 22. Relative suitability analysis for commercial fishing data layers. Ranges from 0 (Low suitability) to 1 (High suitability).

Summary of Industry and Recreation Requirements

In general, commercial fishing activity data (Figures 16-20) from 2015 – 2016 showed low overlap with the AOI. There was no overlap with bottom trawls, seines, pots or traps and low overlap with dredge fishing. There was no overlap with the Herring and Monkfish fishery efforts. The multi-species effort (including the Herring, Monkfish, and Mackerel fisheries) had low effort in the two most western cells of the AOI. Surfclam fishing activity is moderately high in the southwestern potion of the AOI as well. Although both pelagic species and squid fisheries have low effort, these fisheries are present in the Northeastern corner of the AOI and the southwestern corner of the AOI. Notably the scallop fisheries have overlap in the western (outer most) edge of the AOI. Scallop abundance within the AOI in low. However, given the value of the fishery, it is important to note that fishing efforts did occur in the outer limits of the AOI. All cells in the AOI are also in the scallop management area, and outside of the surfclam management area. For more information on many of these fisheries, please refer to Table 11, which lists the management groups in the area.

Table 11. Management Groups working in the area (GARFO 2018).

Management Groups
Southern New England Management Area
Waters Off New Jersey Management Area
Red Crab Management Unit
Tilefish Management Unit
Skate Management Unit
Monkfish Management Unit
Lobster Management Area 4
Herring Management Area 2

For recreational activities, primary diving sites and whale watching areas were considered. The whale watching area overlap with the eastern portion of the AOI, marginally dropping scores based on the scoring schema. Recreational diving did not interact with the AOI.

BIOLOGY

Biological considerations were comprised of observational data and the management areas meant to add extra protection to the organisms. We considered Greater Atlantic Region (GARFO) Section 7 Consultation Areas for endangered species, whale observations, sea turtle observations, seabird nesting and foraging behaviors, and species richness.

Seabirds are present and vary temporally and spatially throughout the year. All seabird nesting colonies are located across Long Island Sound and are approximately 25 – 30 km away from the AOI (Figure 23). Even though seabird foraging may occur in the AOI, core abundance of piscivorous (fish-eating) seabirds, including divers and pursuit plungers, were relative low when looking at the Mid-Atlantic scale.

Certain cetacean species consistently migrate, forage, and calve in the North-Atlantic region. Two areas that highlight these behaviors are the North Atlantic Right Whale management area, and the Fin Whale foraging and calving Section 7 areas, overlapping all of the AOI cells (Figures 25, 26). Observational data, provided by NYSERDA seasonal digital aerial surveys conducted by the New York Department of Conservation, indicated Fin whales, Humpback whales, Sei whales, and one North Atlantic Right Whale were sited (Figure 27). However, there were no sighting in the AOI. These observations should act as an indicator that whales do move through the area, and should be reflected in monitoring efforts if farm sighting occurs.

As with cetaceans, Loggerhead, Leatherback, Kimp's Ridley, and Green Sea Turtles are highly managed in the United States (Figure 24). NYSERDA seasonal digital aerial sea turtle surveys conducted by the New York Department of Conservation (Fall 2016 – Winter 2017) indicate multiple Sea Turtle species, predominantly Loggerheads, move through the AOI, when coming into nest, and leaving the nesting location. There may also be foraging occurring in these areas as well. These data serve as an indicator that sea turtles do move through the area, and should be reflected in monitoring efforts if farm sighting occurs. Summer seasons appeared to have the highest densities for both Loggerhead and Leatherbacks.

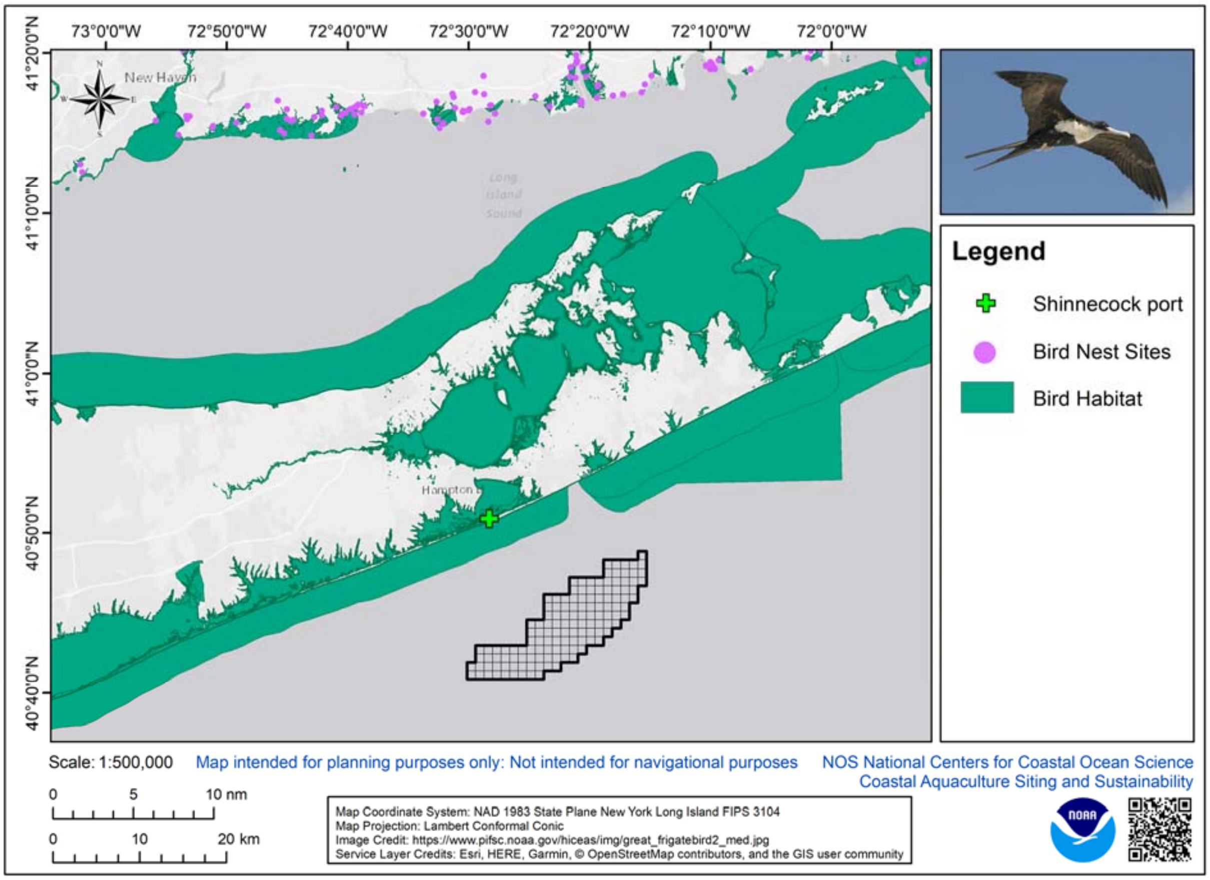


Figure 23. Seabird nesting sites (pink dots) and bird habitat (green area) in the area surrounding the area of interest. All seabird nesting colonies are located across Long Island Sound and are approximately 25 – 30 km away from the AOI. Even though seabird foraging may occur in the AOI, core abundance of piscivorous (fish-eating) seabirds, including divers and pursuit plungers, were relative low when looking at the Mid-Atlantic scale.

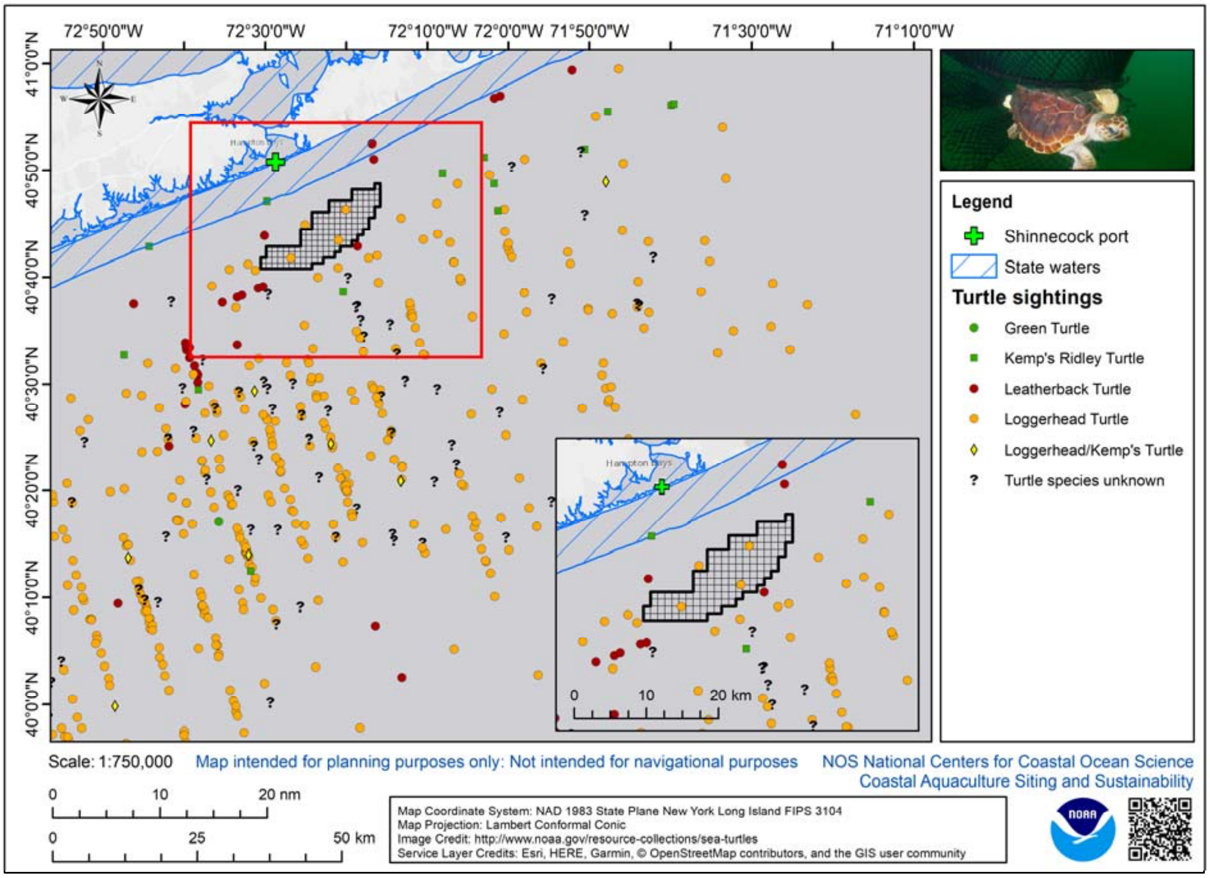


Figure 24. Sea turtle sightings from quarterly aerial surveys conducted by the New York Department of Conservation (Fall 2016 – Winter 2017).

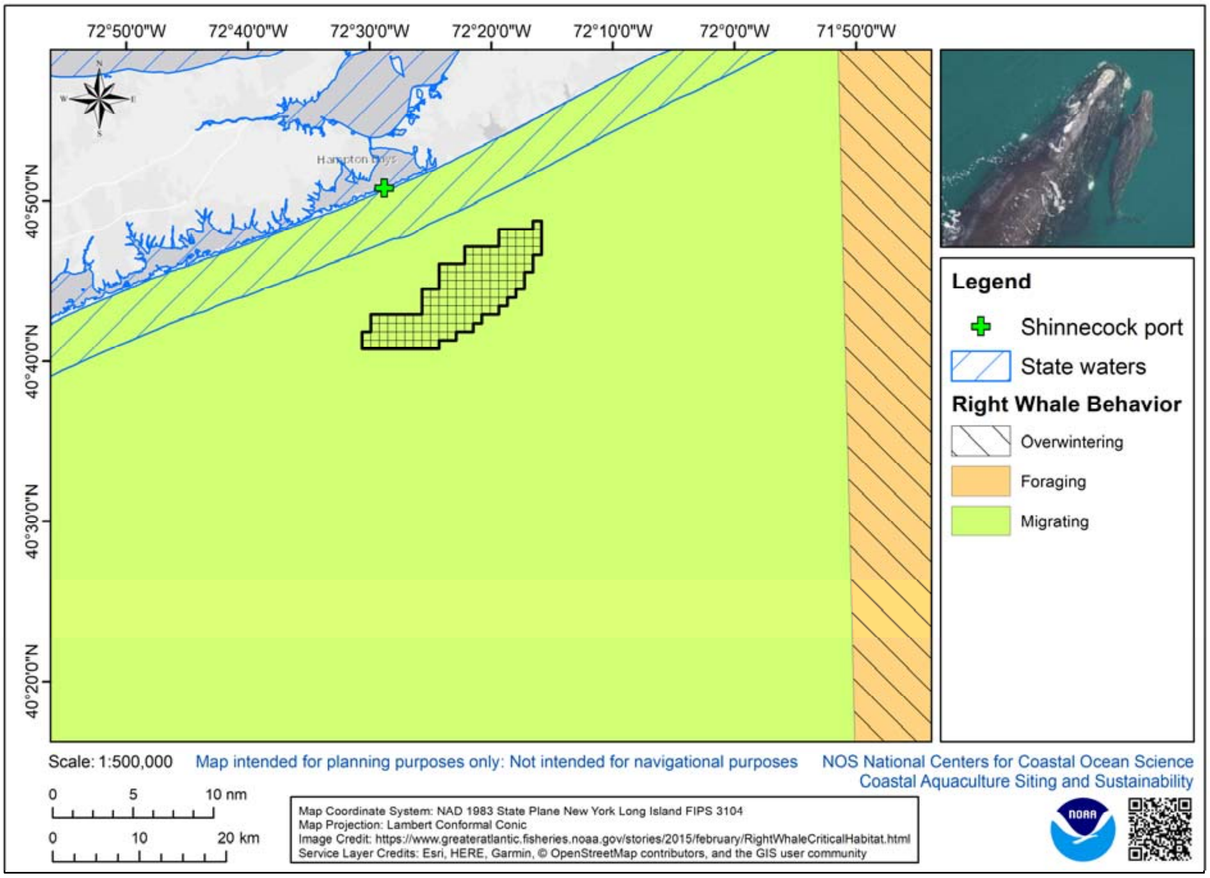


Figure 25. Section 7 North Atlantic Right Whale migratory management area. All of the AOI is in the Section 7 area.

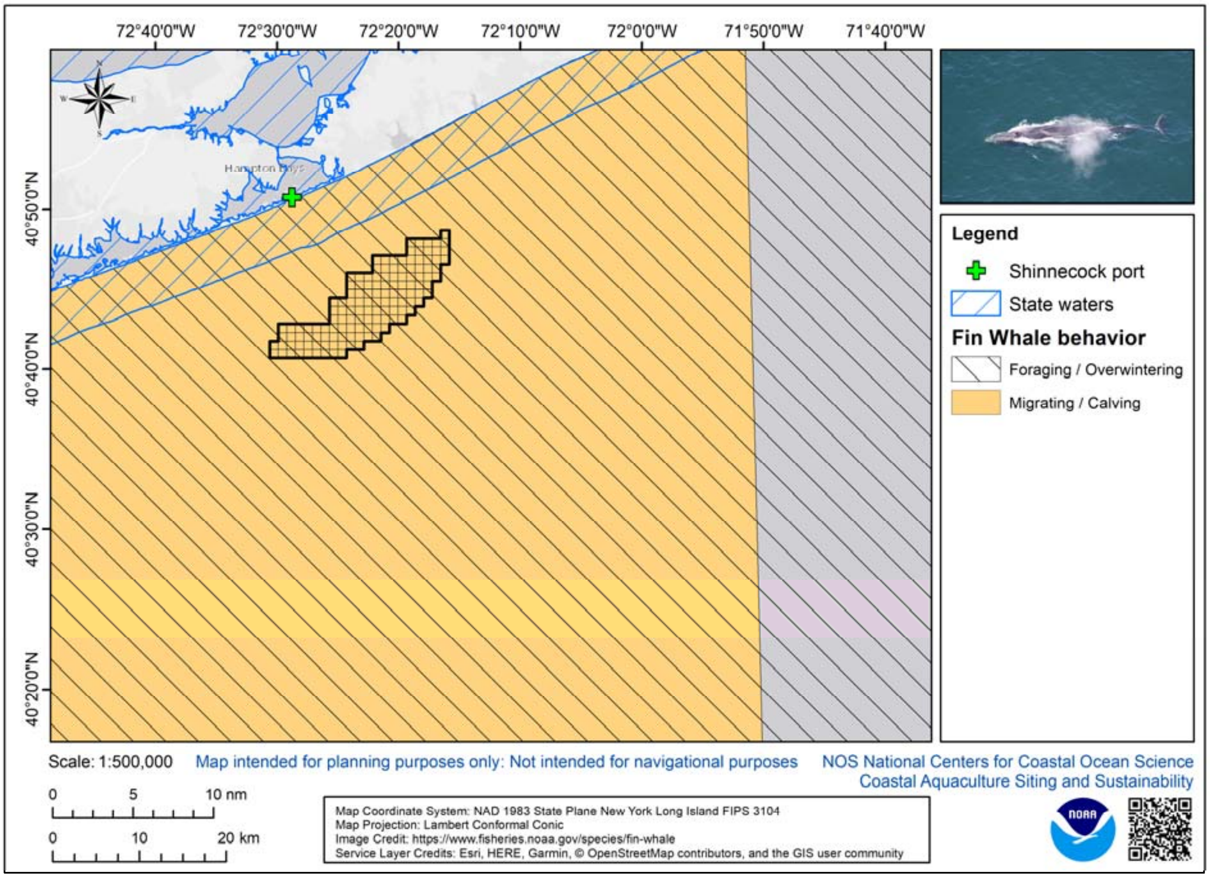


Figure 26. Section 7 Fin Whale management area as they forage, overwinter, migrate through, and calve in this area.

Summary of Biological Requirements

Seabirds had low abundance, high species richness (without a measure of evenness), which is expected for the US Eastern seaboard (Curtice et al. 2016). Gear designed to prevent birds from reaching the fish generally deters most seabirds.

Whales and turtles in the area are a major concern as they are endangered species and uncertainty lies in their exact movements from year to year. However, gear types for finfish cages include mooring lines that are taught (as opposed to free hanging) reduces the likelihood of entanglement for organisms. Also, monitoring plans can aid in the prevention of entanglements for whale and turtle species.

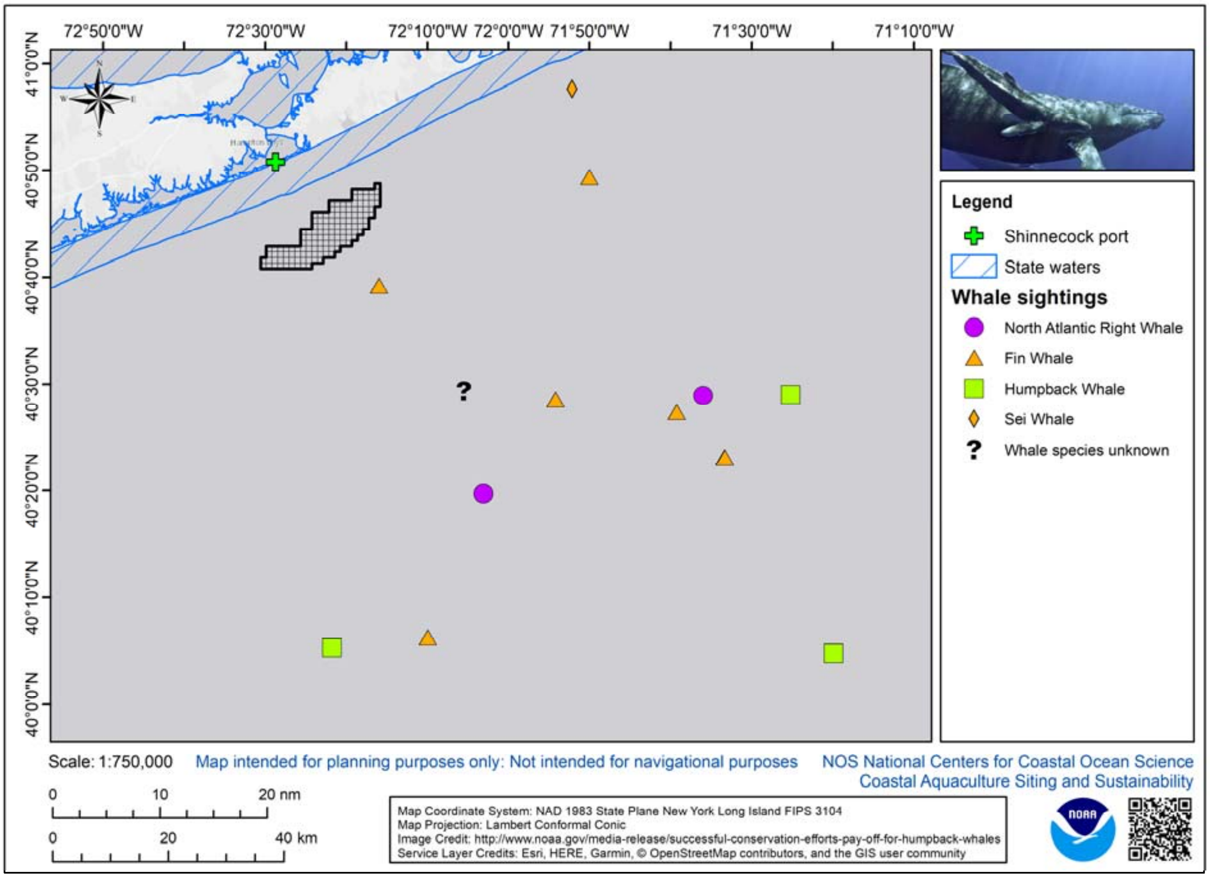


Figure 27. Large whale sighting from quarterly aerial surveys conducted by the New York Department of Conservation (Fall 2016 – Winter 2017).

Final suitability

The final suitability score for each cell, based on the scoring schema for all parameters considered, is shown in Figure 28 and 29. This indicates that there is no cell that is ideal for suitable sighting, but cells that are highly suitable relative to others considered given the parameters considered, can be seen in the figure. From this matrix of cells and relative suitability, we can then develop alternative sites. However, because they are proportionally weighted, it is important to determine what the major conflicts are for each cell, and then for the group of four cells that would comprise the farm site. Sensitivity analyses indicated which conflicts were present in all of the most suitable cells. From here group of four cells were combined to formulate three final alternative farm sites. Importantly, these alternatives represent the size needed for one farm site, but surrounding cell values should also be considered if a different farm shape is needed.

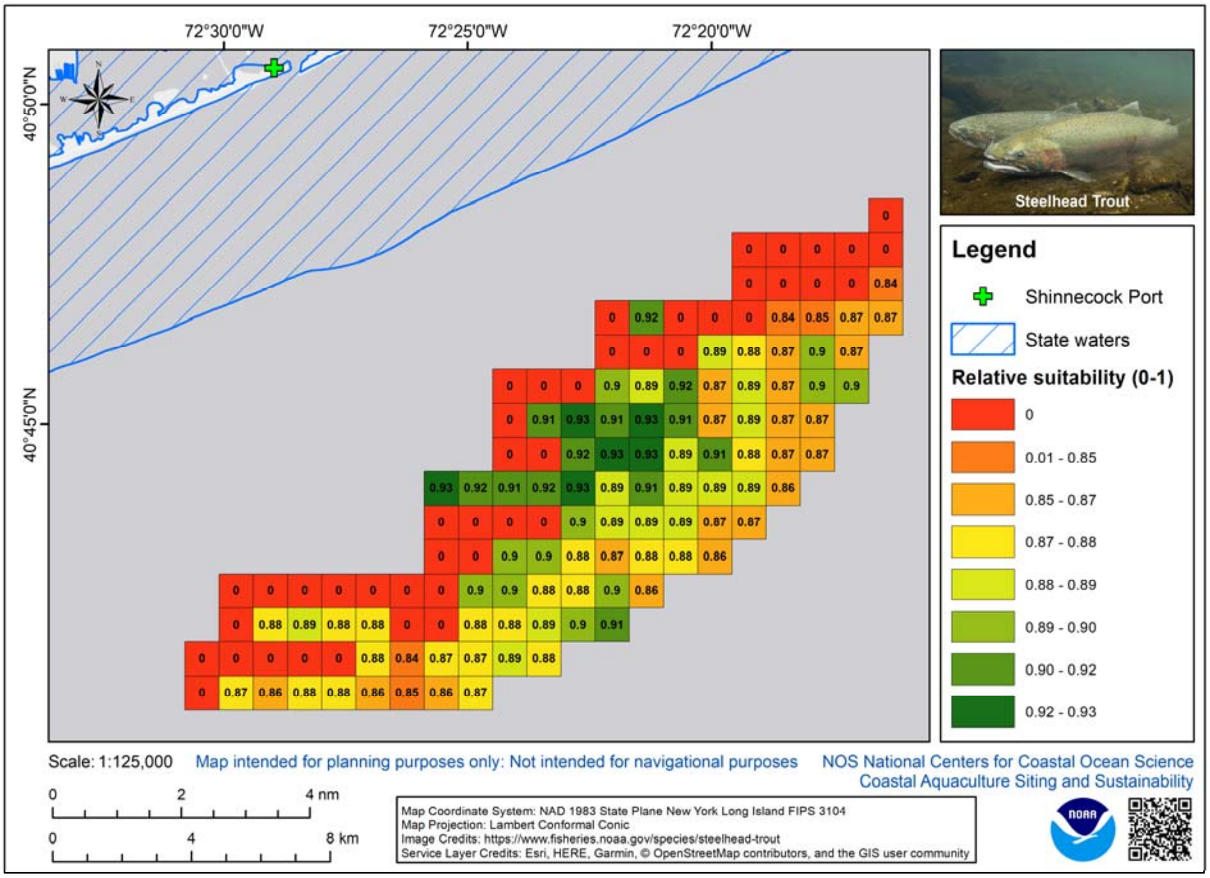


Figure 28. Relative suitability analysis for all data layers equally weighted. Ranges from 0 (Low suitability) to 1 (High suitability).

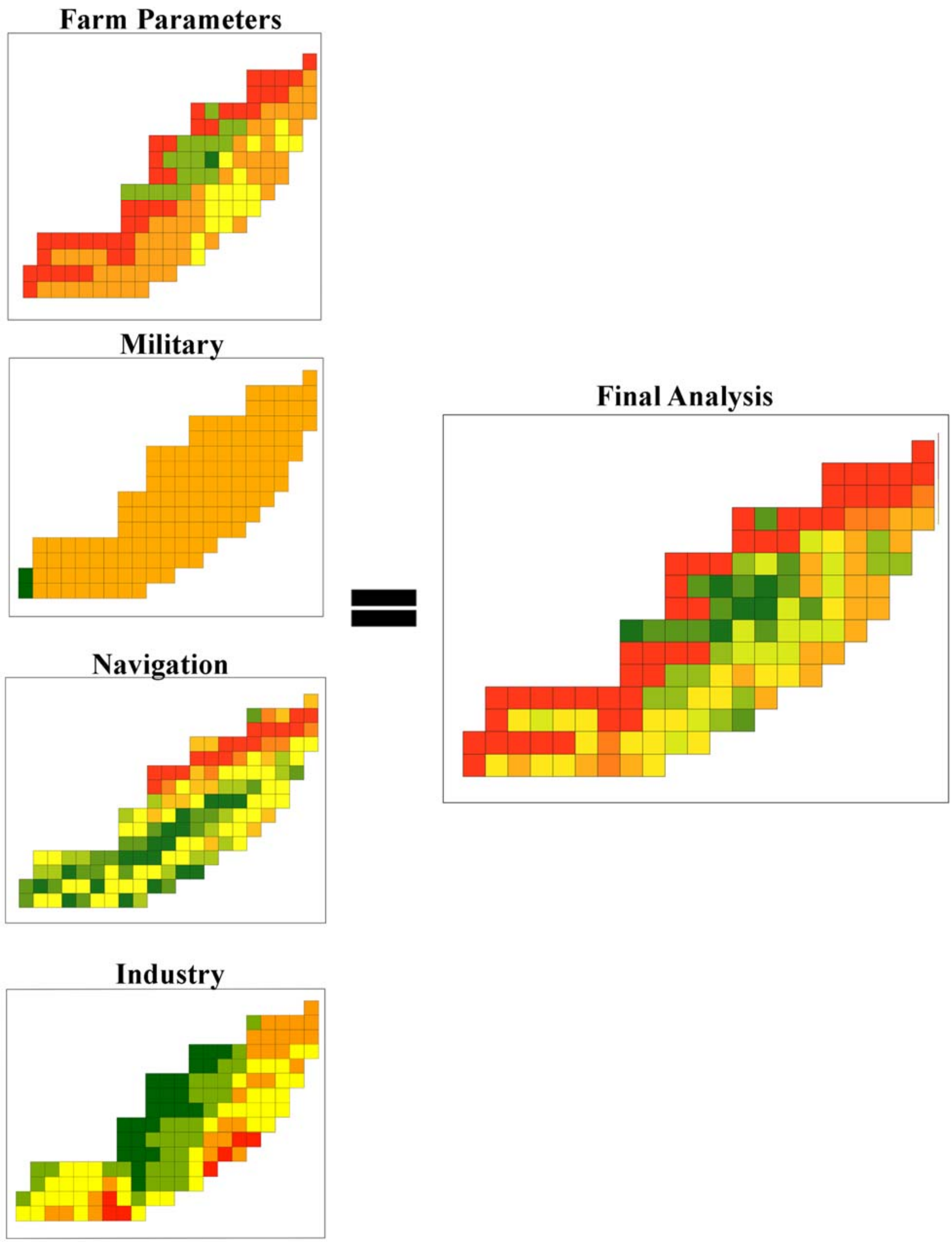


Figure 29: Relative scoring for each major categorical grouping and the final proportionally weighted suitability analysis. In the final analysis map, red is least suitability and green cells are most suitable.

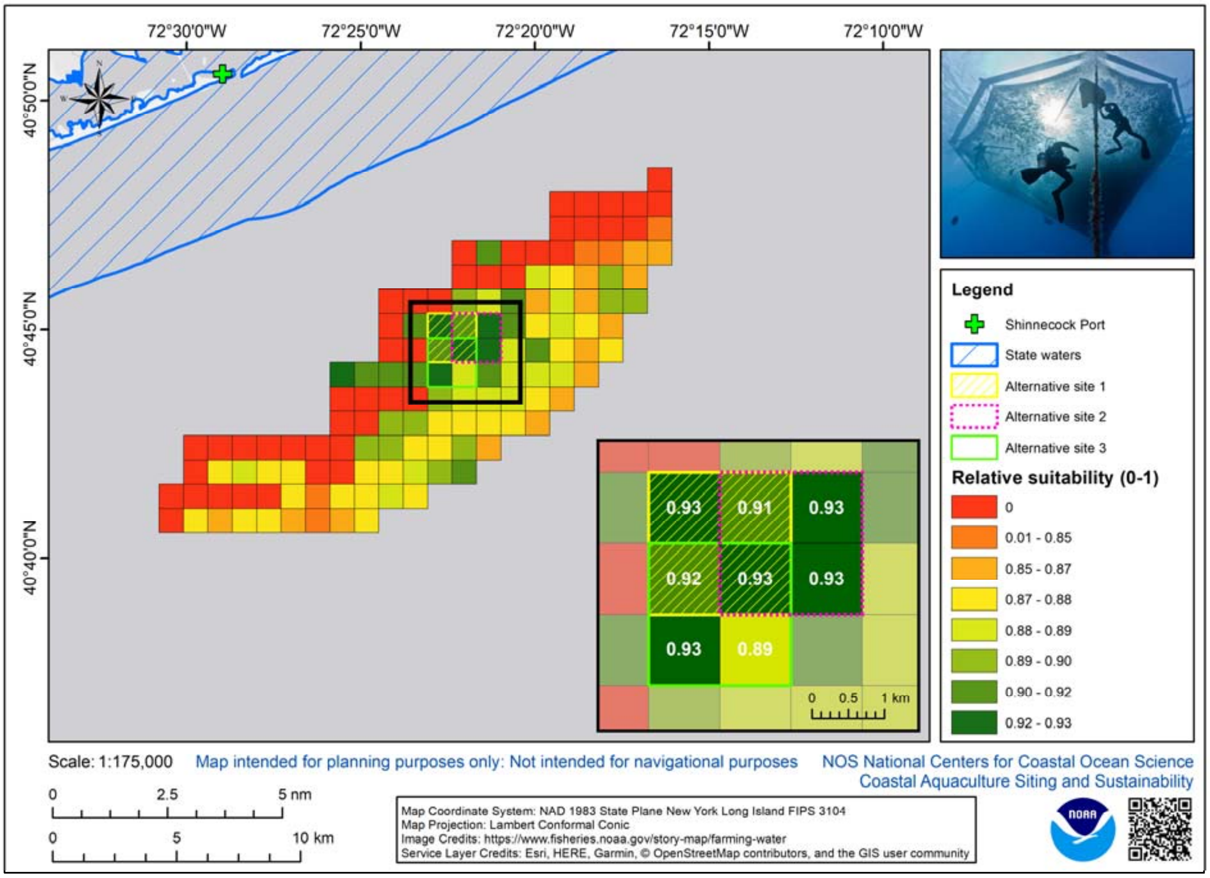


Figure 30. Relative suitability analysis for all data layers equally weighted. Ranges from 0 (Low suitability) to 1 (High suitability). Three alternative sites identified as having high suitability.

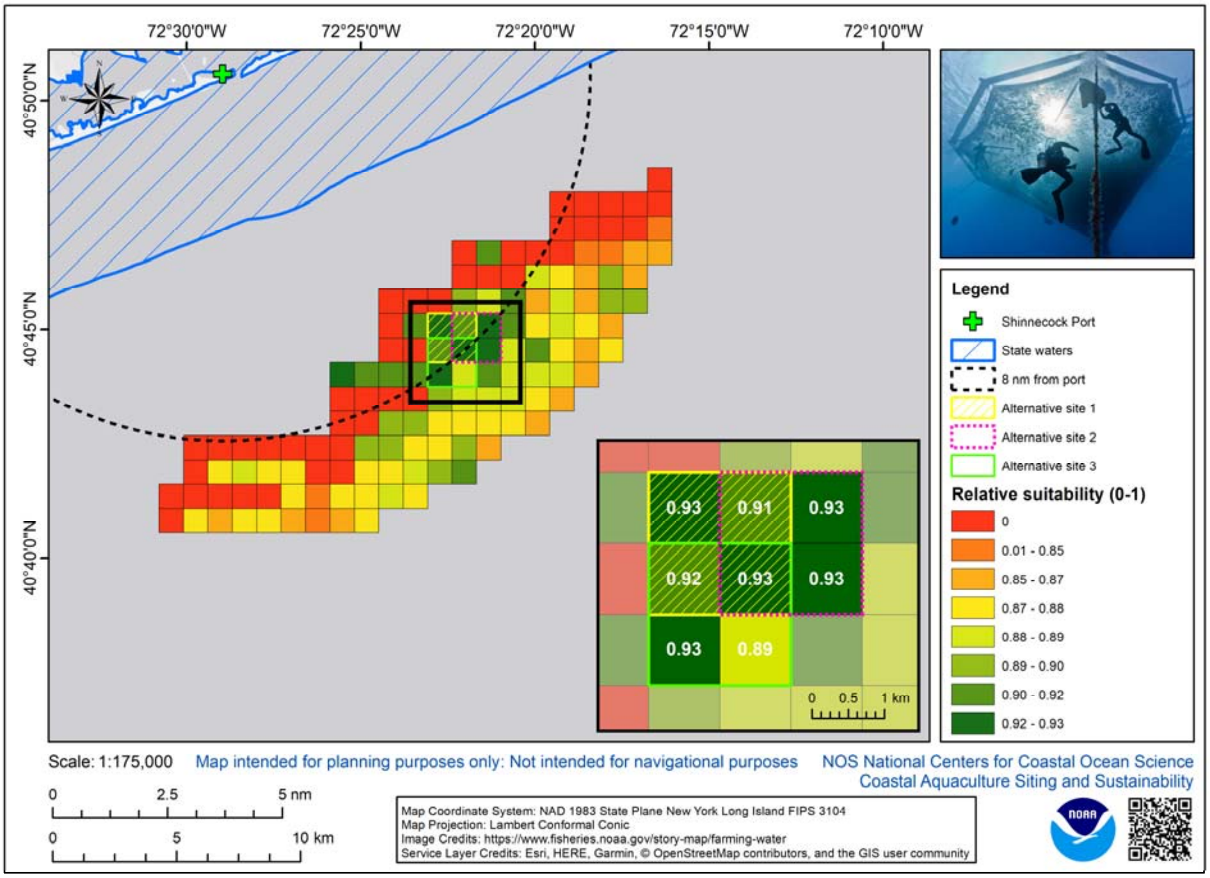


Figure 31. Relative suitability analysis for all data layers equally weighted with 8 nm distance from port line displayed. Ranges from 0 (Low suitability) to 1 (High suitability). Three alternative sites identified as having high suitability.

Table 12. Mean relative suitability score for each alternative site for each weighted category.

Data Layer	Alternative 1	Alternative 2	Alternative 3
Distance from Port	1	1	0.81
Depth	0.50	0.63	0.50
Substrate	1	1	1
Military operating area	0.50	0.50	0.50
Submarine cable	1	1	1
Vessel Traffic Cargo	0.85	0.85	0.90
Vessel Traffic Tanker	0.85	0.90	0.95
Vessel Traffic Tug and Tow	0.80	0.80	0.80
Vessel Traffic Fishing	0.90	0.93	0.93
Vessel Traffic Passenger	1	1	1
Vessel Traffic Pleasure/Sailing	1	1	1
Vessel Traffic Other	1	1	1
Herring commercial fishing	1	1	1
Monkfish commercial fishing	1	1	1
Multispecies commercial fishing	1	1	1
Pelagic commercial fishing	0.98	0.98	1
Scallop commercial fishing	1	1	0.95
Surf clam and quahog commercial fishing	1	1	1
Squid commercial fishing	0.98	0.98	1
Scallop abundance	1	1	0.95
Commercial whale watching	1	0.88	1

Table 13. Relative suitability scores for the farm parameters, military, navigation, industry, biology, and then in total with the number of layers used for each calculation for the three alternative sites.

Site	Farm n=3	Military n=1	Navigation n=8	Industry n=9	Total n=21
Alternative 1	0.83	0.5	0.93	0.99	0.92
Alternative 2	0.88	0.5	0.93	0.98	0.93
Alternative 3	0.77	0.5	0.95	0.99	0.91

DISCUSSION

The constraints analyzed within this analysis are known potential ocean use conflicts. Given the multiple established use of ocean space requires determination of level of conflict. All alternative sites have little interference with commercial fishing or recreational activities in the area. The military and transportation both have established areas and zones (e.g., areas to avoid, danger zones, shipping fairways, etc.). Mean relative suitability scores ranged from 0.91 to 0.93 for the three alternative sites (Table 12 and 13). Alternative site 2 had the highest suitability for the farm parameters as it was slightly deeper than the other two alternatives. Alternative site 3 was the most suitable given the navigational parameters as less vessel traffic intersected it; however, the vessel traffic is quite low for all alternatives. All alternative sites are located in the Narragansett Operating Area, and are in the Section 7 North Atlantic Right Whale, Fin Whale, and Sea Turtle areas. For permitting purposes, further analyses may be required to determine compatibility with military activities and careful planning with protected resources to determine the least impactful gear type and configuration to avoid whale and sea turtle interactions. For example, during the summer months when sea turtle densities are the greatest, increased monitoring may be needed. Apart from the military and protected resource conflicts, the three alternative sites display little to no conflict with submarine cables, vessel traffic, and commercial fishing activities in this area. All alternative sites are in the Section 7 sea turtle, Fin Whale, and North Atlantic Right Whale areas which will require careful additional consideration along with the other interactions throughout the permitting process.

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United States Geological Survey (USGS) East Coast Sediment Texture Database (2005), Woods Hole Coastal and Marine Science Center

Appendix A

Table A-1. Comprehensive data inventory generated for the Northeast region to inform the Manna siting analysis.

Data Layer:	Source:	Access:
Military		
Danger Zones and Restricted Areas	NOAA Office for Coastal Management (OCM) (2017)	Office for Coastal Management, 2018: Aids to Navigation for US waters, including territories, as of May 2017, https://inport.nmfs.noaa.gov/inport/item/48847
Unexploded Ordnances	OCM (2017)	Office for Coastal Management, 2018: Unexploded Ordnances, https://inport.nmfs.noaa.gov/inport/item/48930
Narragansett Operating Area	OCM (2017)	Office for Coastal Management, 2018: Military Operating Area Boundaries: Atlantic / Gulf of Mexico, https://inport.nmfs.noaa.gov/inport/item/48896
Special Use Air Space	OCM (2017)	Office for Coastal Management, 2018: Military Operating Area Boundaries: Atlantic / Gulf of Mexico, https://inport.nmfs.noaa.gov/inport/item/48896
Industry and Recreation		
Pipelines		
Submarine Cables	OCM (2017)	Office for Coastal Management, 2018: NOAA Charted Submarine cables in the United States as of December 2012, https://inport.nmfs.noaa.gov/inport/item/48901.
EPA Ocean Disposal Sites	OCM (2017)	Office for Coastal Management, 2018: Ocean Disposal Sites, https://inport.nmfs.noaa.gov/inport/item/48905
Wind and Marine Hydrokinetic Planning Areas	OCM (2017)	**BOEM** https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan/Area-for-Consideration**;** https://metadata.boem.gov/geospatial/boem_renewable_lease_areas.xml
Marine Minerals and Sand Resource Blocks	OCM (2017)	**BOEM** http://metadata.boem.gov/geospatial/SandGravelLeaseAreas_unrestricted.xml
Existing Aquaculture Areas		Office for Coastal Management, 2018: Aquaculture in Coastal and Marine US Waters, https://inport.nmfs.noaa.gov/inport/item/48850
Commercial Fishing Activity		
Scallop	NMFS, VMS, RPS (2015 - 2016)	Northeast Ocean Data Portal (Northeast Regional Ocean Council (NROC) - Northeast Ocean Data Working Group
Surf clam	NMFS, VMS, RPS (2015 - 2016)	Northeast Ocean Data Portal
Squid	NMFS, VMS, RPS (2015 - 2016)	(Northeast Regional Ocean Council (NROC) - Northeast Ocean Data Working Group
Herring	NMFS, VMS, RPS (2015 - 2016)	Northeast Ocean Data Portal
Monkfish	NMFS, VMS, RPS (2015 - 2016)	(Northeast Regional Ocean Council (NROC) - Northeast Ocean Data Working Group

Multi-species (herring, squid, mackerel)	NMFS, VMS, RPS (2015 - 2016)	Northeast Ocean Data Portal
Pelagic species	NMFS, VMS, RPS (2015 - 2016)	(Northeast Regional Ocean Council (NROC) - Northeast Ocean Data Working Group
Navigation		
Principal Ports		Office for Coastal Management, 2018: Principal Ports, https://inport.nmfs.noaa.gov/inport/item/48918
Aids to Navigation		Office for Coastal Management, 2018: Aids to Navigation for US waters, including territories, as of May 2017, https://inport.nmfs.noaa.gov/inport/item/48847
Environmental Sensors and Buoys		Northeastern Regional Association of Coastal Ocean Observing Systems (2017)
Artificial Reefs		Office for Coastal Management, 2018: Artificial Reefs, https://inport.nmfs.noaa.gov/inport/item/48851
Wrecks and Obstructions		https://www.nauticalcharts.noaa.gov
Coastal Maintained Channels		Army Corps of Engineers (ACE); NOAA OCS 2015
Shipping Lanes		OCS 2017 (39986)
AIS Vessel Density (including total count and by vessel type)		Office for Coastal Management, 2018: 2014 United States Automatic Identification System Database, https://inport.nmfs.noaa.gov/inport/item/48845
Anchorage Areas		Office for Coastal Management, 2018: Anchorage Areas, https://inport.nmfs.noaa.gov/inport/item/48849
Natural Resources		
Deep Sea Coral observations		DOC/NOAA/NMFS/OHC/DSCRTP
Hardbottom Habitat and Predicted Hardbottom Habitat		NOAA BioGeo (2018)
Cetacean Predicted Density and Distribution		MDAT
SAV		This data was compiled by SeaPlan using datasets from the Maine Department of Marine Resources, Bureau of Resource Management, Maine Office of GIS, University of New Hampshire, New Hampshire Department of Environmental Services, NH GRANIT (New Hampshire Geographically Referenced Analysis and Information Transfer System), Massachusetts Department of Environmental Protection, MassGIS, Rhode Island Eelgrass Task Force, Virginia Tech University/US Fish and Wildlife Inventory, National Wetlands Inventory Program, Connecticut Department of Energy and Environmental Protection
Essential Fish Habitat		NOAA NMFS
Habitat Areas of Particular Concern		NOAA, National Marine Fisheries Service, Office of Habitat Conservation (2010)
Marine Protected Areas		https://nmsmarineprotectedareas.blob.core.windows.net/marineprotectedareas-prod/media/data/MPAI_2017_metadata.pdf

Section 7 management areas		NYSERDA seasonal digital arial surveys conducted by the New York Department of Conservation
Oceanographic and Biophysical		
High-resolution bathymetry	10 m	Eakins et al. (2009)
Water Temperature		Montauk Point buoy (Station 44017, 40.693, -72.049)
Current Speed and Direction	FV-COM model	University of Massachusetts-Dartmouth School for Marine Science and Technology (SMAST), Woods Hole Oceanographic Institution (WHOI), RPS Applied Science Associates (RPS ASA)
Salinity		Hycom
Significant Wave Height (Hs)		Montauk Point buoy (Station 44017, 40.693, -72.049)
Surficial sediment		Anderson, M. G., Greene, J., Morse, D., Shumway, D. and Clark, M (2010) Benthic Habitats of the Northwest Atlantic in Greene, J.K., M.G. Anderson, J. Odell, and N. Steinberg, eds. The Northwest Atlantic Marine Ecoregional Assessment: Species, Habitats and Ecosystems. Phase One. The Nature Conservancy, Eastern U.S. Division, Boston, MA.
Administrative Boundaries		
Submerged Land Acts boundary		BOEM Mapping and Boundary Branch *(2010)*
Cultural		
SCUBA diving		SeaPlan, Surfrider, and Point 97
Commercial Whale Watching areas		SeaPlan, Surfrider, and Point 97